OSIPP Discussion Paper : DP-2001-E-004

Theories of Dynamic Pricing and the Japanese Retail Gasoline

30 November 2001

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【Summary】The purpose of this paper is to estimate models for retail price of gasoline based on the prediction deriving from the recent infinitely repeated game theories, supergame theories. The prediction implies that both the future changes and the unexpected shock in the economic environment, where firms faces, do have an impact on the current retail price of gasoline. Using monthly time series data on Tokyo and Osaka for the 1990's, this paper shows evidence consistent with the implication of the theories. Some evidence presented also suggests the behavior of retail prices has changed over the time period being examined.

Theories of Dynamic Pricing
and the Japanese Retail Gasoline Market

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Abstract: The purpose of this paper is to estimate models for retail price of gasoline based on the prediction deriving from the recent infinitely repeated game theories, supergame theories. The prediction implies that both the future changes and the unexpected shock in the economic environment, where firms faces, do have an impact on the current retail price of gasoline. Using monthly time series data on Tokyo and Osaka for the 1990's, this paper shows evidence consistent with the implication of the theories. Some evidence presented also suggests the behavior of retail prices has changed over the time period being examined.

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1. INTRODUCTION

The purpose of this paper is to estimate the behavior of the retail price of gasoline in Tokyo and Osaka using the predictions from several dynamic pricing models. These predictions are based on the recent infinitely repeated game theories, supergame theories. The imprecation of these theories shows that the expected future changes and the unexpected future changes in the economic environment, where firm face (for example, demand or cost conditions) will affect their current price setting if the firms engage in competition in a repeated game context [see, for example, Green and Porter, 1984; Rotemberg and Saloner, 1986; and Haltiwinger and Harrington, 1991]. A second purpose of the paper is to examine the impact of deregulation of the oil industry on the behavior in Tokyo and Osaka in Japan. Different responses to current and future economic conditions by firms in Tokyo and Osaka provide one explanation for differing behavior of gasoline prices in the two prefectures.

The paper is organized as follows. In section 2, a brief survey of recent studies relating to the Japanese and the North American oil industries are presented. To examine how an interaction in long run between gas stations influences the direction of the behavior of retail price, the section 3 surveys several supergame theories including the situation of imperfect monitoring. Section 4 details the models to be estimated, while section 5 describes the data used. Estimated results are presented in section 6.

2. RESEARCH ON THE OIL INDUSTRY

At the end of March 1996, the provisional law relating to the importation of specified petroleum products (Tokutei sekiyu seihin yunyu zantei sochiho, called Tokusekiho) that restricted imports of specified petroleum products (gasoline, kerosene, light oil) to a certain number of companies was abolished. As a result, the importation of specified petroleum products was liberalized. In June 1994, it became clear that the Tokusekiho would be abolished at the end of March 1996. Despite this liberalization, total imports of specified petroleum products relative to total production in Japan have been very small, and the number of new importers of these products has remained rather small. At around the same time the government made the decision to abolish the Tokusekiho, the retail price of gasoline began to fall a little sharply. As a result, the media has often suggested the abolition of the Tokusekiho was a successful case of deregulations.

There have been several recent studies of Japanese oil industry. Prior to the actual abolition of the Tokusekiho, Chida [1996] provides some simulation results that suggest that the wholesale price of gasoline will fall as a result of the Tokusekiho's abolition. Onishi et al.'s [1997] graphical analysis of the national retail price of gasoline suggests that the abolition significantly reduced the retail price of gasoline. Goto's [1999a] analysis of the impact of the protection provided by Tokusekiho showed that it was associated with an upward shift in the cost function of several of the major Japanese oil refiners. Goto [1999b] applies cointegration analysis to the relationship between the wholesale and retail prices of gasoline and attempts to verify whether the relationship has been affected by the abolition of the Tokusekiho. Goto and McKenzie [2001] shows empirically how the retail gasoline price was influent by the change of the expected future environment firms will face, using recent developments of supergame theories. However, it is difficult for firms to expect the environment perfectly and it should be natural to consider that the volatility of the retail gasoline price is influent by the unexpected change of the environment. This paper attempts to show how the future changes and the unexpected shock in the environment contributes to the fluctuation of the retail or wholesale gasoline market in Japan.

In contrast, using detailed firm level data, Slade [1987 and 1992] suggests that gas stations in Vancouver have set a collusive price rather than a Nash equilibrium price. Borenstein and Shepard [1996] using city level gasoline data for the United States apply the ideas of Rotemberg and Saloner [1986] and Haltiwinger and Harrington [1991] that, in a repeated game context, the future changes in the economic environment (for example, demand and cost factors) will affect current collusive prices. Their evidence indicates that expected future demand and cost changes do influence current gasoline prices, suggesting that gas stations are behaving in a manner consistent with a repeated game.

3. MODELS OF DYNAMIC PRICING

The purpose of this paper is to estimate models for retail price of gasoline based on the prediction deriving from the recent infinitely repeated game theories, supergame theories. The prediction implies that both the future changes and the current unexpected shock in the economic environment, where firms faces, do have an impact on the current retail price of gasoline. Using monthly time series data on Tokyo and Osaka for the 1990's, this paper shows evidence consistent with the implication of the theories. Some evidence presented also suggests the behavior of retail prices has changed over the time period being examined.

It is assumed that firms commit either to a price or a quantity in Bertrand or Cournot competition before unexpected shocks. In Cournot competition, when firms commit to quantity, a shift (price elasticity of supply is zero in the short-run), an unexpected increase (decrease) in demand merely causes an increase (decrease) in the current price with consequential increases (decreases) in profits. In the next period, while the unexpected increase in demand in the previous period does not cause the tripping of the trigger strategy, the unexpected decrease in demand in the previous period does cause the tripping of the trigger strategy so that prices could be expected to fall. That is ute >0 causes pt ^ and pt+1 unchanged, ute <0 causes pt v and pt+1 v, the response in period t is symmetric, but the response in t+1 (and in the subsequent periods the trigger strategy is tripped) is asymmetric.

What about an unexpected increase (decrease) in marginal costs? In Cournot competition, provided marginal cost does not increase above price, since the demand curve does not shift and firms have committed to a particular quantity, there is no change in price. As a result, the trigger strategy is not tripped. That is, current and future prices do not respond at all to an unexpected change in the current marginal costs!

4. ESTIMATED MODEL

The model in section 3 indicates that when gas stations are facing a state of mutual dependence, and behave cooperatively, the collusive price may result from firms forecasting their future economic environment and choosing their behavior accordingly. To take account of this, the following price equation was estimated

$$P_{it} = \alpha_{i0} + \alpha_{i1}Q_{it} + \alpha_{i2}W_t + \alpha_{i3}UQ_{it} + \alpha_{i4}UW_t + \alpha_{i5}EQ_{it+1} + \alpha_{i6}EW_{t+1} + u_{it} \quad (1)$$

where P_{it} is the retail price of gasoline for the ith prefecture at time t, Q_{it} is the quantity of gasoline sold in the ith prefecture at time t, W_t is the national wholesale price of gasoline, E is the expectation operator, and u_{it} is a disturbance. The discussion of several dynamic model in the previous section suggests the coefficients in (1) should have the following signs $\alpha_{i1} < 0$, $\alpha_{i2} > 0$, $\alpha_{i3} > 0$, $\alpha_{i4} > 0$, $\alpha_{i5} > 0$, and $\alpha_{i2} < 0$.

In order to estimate the price equations, it is necessary to calculate the expected values of future demand and wholesale prices in some way. Here, we follow Borenstein and Shepard's [1996] approach of fitting equations for Q and W, and then using the computed predicted values from these equations as estimates of the expected values. The estimated equations are of the following form:

$$Q_{it} = \beta_{i0} + \beta_{i1}Q_{it-1} + \beta_{i2}P_{it-1} + \sum_{j}^{11}\theta_{ji}S_{tj} + \beta_{i3}t + \beta_{i4}t^2 + error \quad (2)$$

$$W_t = \gamma_0 + \gamma_1 W_{t-1} + \gamma_2 W_{t-2} + error \quad (3)$$

where S_{tj} is a seasonal dummy for the jth month. To save space, estimates of equations (2) and (3) are no presented.

5. DATA

The monthly data used in this paper run from October 1990 to October 1999. Data on retail gasoline prices at a prefectural level were obtained from the Monthly Survey of the Market Situation of Oil Products (Sekiyu seihin shijo getsuji chousa) produced by the Japan Energy Economic Research Institute's Oil Information Center (Nihon Enerugi keizai kenkyusho Sekiyu joho senta). This data is obtained from surveys of the price of regular gasoline sold at gasoline stations. The surveys are carried out on the tenth day of each month.

Data on wholesale gasoline prices were obtained from the Nikkei NEEDS database using the price paid by traders who purchase gasoline from refineries and distribute it to gas stations. Data on gasoline prices at the wholesale level are not available at a prefectural level so the wholesale price is treated as being the same across Japan.

Data on retail sales of gasoline at a prefectural level, the price of crude oil, and the number of gasoline-powered vehicles registered in Japan were also obtained from the Nikkei NEEDS database. Although retail price and sales data is available for all 47 prefectures in Japan, the analysis in this paper is limited to the prefectures of Tokyo and Osaka. An examination of the retail prices in these two prefectures suggests that there are some substantial differences in the behavior of retail prices in Tokyo and Osaka after mid-1994.

6. RESULTS

Estimates of equation (4) for Tokyo and Osaka are presented in Tables 1 and 2, respectively. For both prefectures, retail price equations are estimated using three samples: all the data (1990:11-1999:10); the first half of the data (1990:11-1994:5); and the second half of the data (1994:6-1999:10). The time at which the sample is divided into roughly two halves, 1994:6, is when the abolition of the Tokusekiho was formally decided. Estimates using ordinary least squares and instrumental variables are presented; the latter takes account of the possibility that all the explanatory variables in (4) may be correlated with the equation's error. The instruments used varied across the time periods and prefectures being considered, but they were drawn from seasonal dummies, time trend (and its square), lagged demand, lagged wholesale price, current and lagged rebate, current and lagged price of imported gasoline, and current and lagged number of registered gasoline-powered vehicles.

There are two reasons for computing the t-statistics in all cases using Newey-West's [1987] correction. First, the diagnostic tests in most cases provide evidence of strong serial correlation in the error. Secondly, computing the fitted values of expected future quantities and retail prices causes a generated regressor problem [see Pagan, 1986; and McKenzie and McAleer, 1997] that, in general, induces serial correlation and heteroscedasticity in the equation's error. Limitations on the availability of relevant data on a monthly basis severely restricted our attempts to investigate the possibility that it was misspecification of the equation that was causing the significant diagnostic test results.

For Tokyo, all the signs of the estimated coefficients, excluding the expected future quantities, are consistent with the predictions of the Rotemberg and Saloner [1986] model presented in section 3. For all the sample periods, at least one of the expected future variables is statistically significant. This finding is consistent with game theoretic models that suggest future changes in the economic environment will affect current price setting by firms if the firms are engaged in competition in a repeated game context.

For Osaka, the signs of the estimated coefficients, excluding the expected future quantities, are also consistent with the predictions of the Rotemberg and Saloner [1986] model when the whole sample and the first half of the data are used. Both these signs are however reversed for the second half of the data suggesting a structural change around the time the abolition of the Tokusekiho was decided. As with Tokyo, the signs of the estimated coefficients for current and expected future quantities are the opposite of those predicted by the theoretical model. For all the sample periods, at least one of the expected future variables is statistically significant.

7. ACKNOWLEDGEMENTS

The authors wish to thank Masayoshi Matsui and employees of the Fuel, Oil and Fats Newspaper (Nenryo Yushi Shinbun) for providing detailed information on the Japanese oil industry.

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Table 1: Estimated Retail Price Equations for Tokyo

Estimator	1990:11-1999:10 OLS-NW	IV-NW	1990:11-1994:5 OLS-NW	IV-NW	1994:6-1999:10 OLS-NW	IV-NW
Q_{it}	-0.24	-0.26	-.004		-0.016	-0.023
	(6.02)	(7.28)	(3.50)		(3.68)	(3.12)
W_t	2.293	6.211	4.434	4.779	1.404	1.50
	(5.00)	(3.64)	(6.24)	(6.88)	(16.69)	(27.73)
UQ_{it}^{e}					0.020	
					(2.05)	
UW_{t}^{e}		1.096	1.429	1.430	-.0.687	-0.583
		(2.37)	(3.51)	(3.33)	(3.93)	(5.56)
Q_{it+1}^{e}	-0.024	-0.405			-0.028	
	(5.61)	(4.61)			(3.82)	
W_{t+1}^{e}	-1.12	-5.095	-4.671	-4.979		
	(2.66)	(2.86)	(4.81)	(5.41)		
s	1.921	1.932	0.969	1.007	1.87	1.97
R^2	0.978	0.975	0.886	0.750	0.952	0.951
SC	82.90*	71.86*	29.68*	28.33*	53.92*	42.70*
FF	26.73*	54.05*	0.73	16.42	2.38	26.16*
H	0.603	0.045	0.02	0.075	7.13*	0.51
ST	na	5.805	na	1.588	na	1.441

Notes: OLS-NW and IV-NW denote estimation using ordinary least squares (OLS) and instrumental variables (IV), respectively, with the t-statistics adjusted using the Newey-West (NW) correction. Figures in parentheses are absolute values of the t-statistics. s and R^2 denote the standard error of the regression and the coefficient of determination [for models estimated by instrumental variables this is the generalized R^2 measure proposed by Pesaran and Smith, 1994). SC, FF and H denote tests for 12th order serial correlation, functional form misspecification and heteroscedasticity, and are distributed as χ^2 variates with 12, 1 and 1 degrees of freedom under their respective null hypotheses. ST is Sargan's general misspecification test for models estimated by instrumental variables. For these diagnostic tests, a '*' indicates significance at the 5% level. An entry of na, indicates that the ST are inapplicable for models estimated by OLS. Estimates of the constant are not presented.

Table 2: Estimated Retail Price Equations for Osaka

	1990:11-1999:10		1990:11-1994:5		1994:6-1999:10	
Estimator	OLS-NW	IV-NW	OLS-NW	IV-NW	OLS-NW	IV-NW
Q_{it}		-0.0184				
		(4.91)				
W_t	9.764	4.115	5.572	4.797	1.782	1.848
	(2.48)	(3.64)	(5.96)	(8.29)	(4.01)	(4.00)
UQ^e_{it}	0.253	0.276			0.172	0.152
	(7.93)	(4.38)			(3.63)	(3.63)
UW^e_t	2.100		1.990	1.544	-1.662	-1.573
	(2.27)		(2.86)	(2.72)	(3.77)	(4.44)
Q^e_{it+1}	-0.049	-0.478	-0.019	-0.014	-0.0745	-0.061
	(2.27)	(6.62)	(2.93)	(3.20)	(2.23)	(2.02)
W^e_{t+1}	-8.927	-3.058	-6.194	-5.171		
	(2.17)	(2.75)	(4.51)	(5.54)		
s	4.934	4.961	1.296	0.646	5.298	5.282
R^2	0.841	0.841	0.826	0.646	0.774	0.771
SC	94.92*	94.54*	32.38*	33.56*	53.24*	53.03*
FF	45.63*	42.13*	2.21	5.30*	37.19*	36.91*
H	24.09*	24.70*	0.03	0.814	0.05	0.013
ST	na	2.537	na	13.38	na	22.80

Notes: As for Table 1.