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Risk Assessment of Power Plant Investment by Three Level Ordered Probit Model Considering Project Suspension

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Abstract

Under the deregulation in electricity, electrical power industries encounter may risks. The electrical power supplier should evaluate future uncertainty adequately and plan an appropriate investment project. Therefore, it is necessary to develop a new method to evaluate the risks for the investment. We have already proposed two new asset evaluation methods. One is the method using a net present value based on utility indifference pricing (UNPV method) and the other is probit model which simplifies UNPV method. We have checked their effectiveness through the project evaluation of a gas thermal power plant. In this paper, we propose three level ordered probit model. In the conventional probit model, we pay attention only to execution and rejection of the project. Some project should be suspended because the evaluation of the project is positive, but relatively low. In the new three level ordered probit model, we introduce suspension status for the project evaluation adding to execution and rejection. We apply it to the project evaluation of gas thermal power plant and show the effectiveness of the new method.

Introduction

Under the electricity deregulation, uncertainty, that is, “risk” of the electrical power industry increases. The electrical power supplier should evaluate future uncertainty adequately and plan the appropriate investment project.

As evaluation methods of the investment, NPV (Net Present Value) method is well known [1]. However, the NPV method does not evaluate the risk to investors because it evaluates only the future cash flow by present value. It is important to expand to evaluate and reflect the attitude of investors for the risk adequately. Therefore, we have already proposed the project assessment method based on “utility indifference pricing” of the expected utility theory. This method is called the utility indifference net present value (UNPV) method [2][3]. In UNPV method, the utility function is employed to evaluate investors’ attitude for the risk. The utility function presents the satisfaction degree of investors when they invest a unit of their property. We have already applied UNPV method to assess gas thermal generation projects. However, it is difficult to identify the utility function itself, and if possible, it is also difficult to identify the parameters of the function.

To avoid using the utility function, we propose the probit model simplified UNPV method [4][5]. When we pay attention only to the execution of the project, the project can be expressed by a binary variable, that is, execution or rejection. The probit model is a kind of the regression equation, of which dependent variable is the binary variable, that is, execution or rejection. Its explanatory variables are average and variance of net present values obtained by many trials. Considering the uncertainty only in the fuel and electricity prices, we compose the probit model to evaluate gas thermal power plant. It is found that the probit model is effective for the project evaluation.

Conventionally, we pay attention only to the execution or rejection of the project and evaluate the investment by two level ordered probit model. Some project should be suspended because the evaluation of the project is positive, but relatively low. In this paper, we propose three level ordered probit model added suspension status to execution and rejection status for the project evaluation. We will apply the three level ordered probit model to the evaluation of gas thermal power plant project considering the uncertainty in fuel prices and electric power prices. We also examine a range of suspension by changing volatility.

UNPV Model

Net Present Value Method

It is assumed that the time series of cash flow $X = \{X_n, n = 1, 2, \cdots, N\}$ is obtained from the project every year in future. Let *RNPV* be a random net present value obtained from one trial. *RNPV* is defined as (1).

$$RNPV\,(X) = \left\{ \sum_{n=1}^{N} \left(X_n / (1+r)^n \right) \right\} - I \qquad (1)$$

where N is the designated year and r is a risk-free rate. I represents the construction cost of the project. The net present value *NPV* is given by the expectation of *RNPV*.

$$NPV(X) = E[RNPV(X)] \quad (2)$$

where $E[\cdot]$ denotes the expectation. According to net present value (NPV) method, it is decided to execute the project when $NPV > 0$.

Utility Indifference Net Present Value Method

In the framework of the expected utility theory, the uncertain return *RNPV* is evaluated by (3).

$$\mathrm{E}[u(-\nu + RNPV(X))] = 0 \quad (3)$$

where $u(x)$ is the utility function with $u(0)=0$. The utility function $u(x)$ presents the satisfaction degree of investors when they invest their property x. As most investors in electrical power industries seek to avoid their risk, the utility function $u(x)$ is assumed to be expressed by (4).

$$u(x) = 1 - \exp(-\beta x) \qquad \beta > 0 \quad (4)$$

where β is a positive constant. Eq. (4) presents the utility function of risk aversion type. On the contrary, if the utility function is given as $u(x)=x$, it presents the risk neutral type.

The value of *RNPV* as "utility indifference price" is defined by the value of ν. It means that the expected return is equal to 0 if the value ν is paid for the right to obtain the uncertain return *RNPV*, and in this con-text, *RNPV* and ν are balanced. We call ν as "utility indifference net present value (UNPV)". When UNPV $\nu > 0$, the project should be executed.

Three Level Ordered Probit Model

Composition of Two Level Ordered Probit Model

Though UNPV method is effective, it is difficult to identify parameters of the utility function. To avoid using the utility function, the probit model simplified UNPV method has been proposed.

Using a plenty of *RNPV*, we can calculate average *E*[*RNPV*] and variance *V*(*RNPV*). We also can know the execution or rejection by UNPV ν. Then, UNPV ν is transformed to a binary variable ν^* as follows

if $\nu < 0$, then $\nu^* = 0$ (rejection)

if $0 < \nu$, then $\nu^* = 1$ (execution) (5)

The binary variable ν^* represents execution or rejection of the project.

RNPV denotes as *Z* shortly. By changing conditions of the project, many sets of {ν^*, *E*[*Z*], *V*(*Z*)} can be obtained. Using these sets, we compose a regression equation as the probit model. Average *E*[*Z*] and Variance *V*(*Z*) are the explanatory variables. The dependent variable $\hat{\nu}$ represents execution or rejection of the project. The probit model is composed as (6).

$$\hat{\nu}_i = \hat{\beta}_1 + \hat{\beta}_2 E[Z_i] + \hat{\beta}_3 V(Z_i) \quad (6)$$

where $\hat{\beta}_i$ is the regression coefficient obtained by maximum likelihood estimation. To assess the project, expected value and variance of *RNPV* (=Z) are substituted to (6). If $\hat{\nu}_i > 0$, the project should be executed.

Expansion to Three Level Ordered Probit Model

In the consequence of UNPV method, there are small positive values of ν. According to UNPV method, the project should be executed as the value ν is positive. However, investors hesitate to execute the project and may suspend it if the value ν is very small. Therefore, we introduce suspension status for the project evaluation adding to execution and rejection. It is possible to evaluate the project value more definitely.

Condition (5) is expanded to a ternary variable ν^* as follows:

if $\nu < 0$, then $\nu^* = 0$ (refusal)

if $0 < \nu < a$, then $\nu^* = 1$ (suspension) (7)

if $a < \nu$, then $\nu^* = 2$ (execution)

Three level ordered probit model is composed as (8) and (9).

$$\hat{\nu}_i = \hat{\beta}_2 E[Z_i] + \hat{\beta}_3 V(Z_i) \quad (8)$$

$$\hat{\nu}_i{}^* = \begin{cases} 0 & if \quad \hat{\nu}_i \le \hat{\gamma}_1 \\ 1 & if \quad \hat{\gamma}_1 < \hat{\nu}_i \le \hat{\gamma}_2 \\ 2 & if \quad \hat{\gamma}_2 \le \hat{\nu}_i \end{cases} \quad (9)$$

where $\hat{\beta}_2$ and $\hat{\beta}_3$ are regression coefficient, $\hat{\gamma}_1$ and $\hat{\gamma}_2$ are threshold value. These parameters are obtained by the logarithm likelihood function. To assess the project, the expected value and the variance of *RNPV* (=*Z*) are substituted to (8). The project is decided to execute $(\hat{\nu}_i{}^* = 2)$, suspend $(\hat{\nu}_i{}^* = 1)$ or rejection $(\hat{\nu}_i{}^* = 0)$ according to the values of $\hat{\nu}_i$ and $\hat{\gamma}_i$.

Simulation Model

Supposed Model of Gas Thermal Power Plant

In this paper, we assess the project of a gas thermal power plant. Only to make the model simple, we set following assumptions.

- ✓ Construction period is not considered.
- ✓ Operating period is 22 years.
- ✓ Only electric power price and fuel price are uncertain. Daily electric power price and fuel price are modeled by the average regression models.
- ✓ Electric power is traded only in day-ahead market.
- ✓ Electric power price does not change by bidding the considered generator.
- ✓ The considered generator sells the rated power for 14 hours a day.
- ✓ Unit commitment cost of the generator is not considered.

These assumptions are affected only to the model which represents the risk of the project. When the risk (uncertainty) from the above assumptions must be considered, it should be built in the model. It is not essential to the evaluation method by the probit model.

Cash Flow Model for Prices

The electric power price EP_i and the fuel price CP_i are shown by the average regression models as (10) and (11), respectively.

$$EP_i = EP_{i-1} \times exp\left\{\left[\alpha_1\left(\mu_1 - x_{1,i-1}\right) - \frac{\sigma_1^2}{2}\right]\Delta_i + \sigma_1\sqrt{\Delta_i}\varepsilon_{1,i}\right\} \quad (10)$$

$$CP_i = CP_{i-1} \times exp\left\{\left[\alpha_2\left(\mu_2 - x_{2,i-1}\right) - \frac{\sigma_2^2}{2}\right]\Delta_i + \sigma_2\sqrt{\Delta_i}\varepsilon_{2,i}\right\} \quad (11)$$

Following the above assumptions, cash flow CF is shown as (12) and represented the uncertainty.

$$CF = \sum_{i=1}^{365}\left(14 \times \left(EP_i - \acute{H} \times CP_i\right)\right) - OMC \quad (12)$$

In this paper, we examine the profit per 1 kWh of the gas thermal power plant for the simplification of calculation. Table 1 shows parameters of the average regression model of electric power price and fuel price. Parameters of the long term price level $\bar{S}$, the mean regressive rate α, and volatility σ of the electric power price and the fuel price are set based on the electric power price data of JEPX [6] and the gas price data of Hanny Hub [7] respectively.

By changing the parameters, many distributions of *RNPV* can be obtained by Monte Carlo simulation. According to the distribution of *RNPV*, investors should decide execution, suspension or rejection originally. However, as it is difficult for investors to make the decision in this paper, the results obtained by UNPV method make the decision, that is, execution, suspension or refusal according to (7).

Table 1. Parameters of average regression model

	Power price EP_i	Fuel price CP_i
$\bar{S}$: Long-term price level	9.0 - 10.3 JPY/kWh	5.7 - 6.5 $/mmBTU
α : Mean regressive rate	70-160	5-40
σ : Volatility	2.5-3.9	0.5-2.0
p_s : Probability of price spike	0%, 0.1-5.0%	0%, 0.1-0.5%
m_s : Multiple rate of spike	1.2-10	2-5
Δ_t : Discrete time	1/365 day^{-1}	
rate : Exchange rate	100 JPY/$	
$\acute{H}$: Generating efficiency	0.79 JPY・mmBTU	
OMC : Operating & maintenance cost	9636 JPY/(kW・year)	
I : Construction cost	2.0×10^5 JPY/kW	
n : Operating period	22 year	
r : Risk-free rate	3 %	

Results of Simulation

Analysis method

We examine the effectiveness of three level ordered probit model by applying to a gas thermal power plant project considering the uncertainty in electric power price and fuel price. To consider the uncertainties in the prices 362 cases are simulated by changing the parameters in Table 1. As each case has 20,000 trials, 20,000 *RNPV*s are obtained in every case.

In addition to the above 362 cases, 240 cases are simulated considering the price spike generated at constant probability P_s with no relation to time series. When the price spike is occurred, the average price during a whole day is assumed to jump up by a certain constant magnification m_s. Cases with spike have 50,000 trials because the probability of spike is relatively small.

The range of suspension is assumed 2 patterns, that is, from 0 to 3000 and from 0 to 5000 for the value ν obtained by UNPV method. According to the value ν, ternary variable ν^* is defined by (7). Thus, as many sets of {ν^*, $E[Z]$, $V(Z)$} can be obtained, three level ordered probit model is composed by 362 cases without spike, 240 cases with spike, and all 602 cases.

Three Level Probit Model for Cases Without Spike

The three level ordered probit model for 362 cases without spike is (13) and (14). The ordered probit model with the suspension range up to 3000 is shown in (13).

$$\hat{\nu} = 3.659 \times 10^{-4}E[Z] - 1.037 \times 10^{-7}V(Z)$$
$$\hat{\gamma}_1 = 1.824, \quad \hat{\gamma}_2 = 2.874 \quad (13)$$

The ordered probit model with the suspension range up to 5000 is shown in (14).

$$\hat{\nu} = 3.682 \times 10^{-4}E[Z] - 1.037 \times 10^{-7}V(Z)$$
$$\hat{\gamma}_1 = 1.860, \quad \hat{\gamma}_2 = 3.501 \quad (14)$$

Table 2 shows the results of the ordered probit model composed by 362 cases without spike. It shows number of inconsistent results with UNPV method and the ordered probit model, consistent ratio R/N with both results, *t*-ratio for regression coefficients of average $E[Z]$ and variance $V[Z]$ and threshold γ_1 and γ_2, and Wald test statistic, sequentially from the top to the bottom. From the results, the value of R/N is about 0.9. Moreover, the absolute values of each *t*-ratio exceed 1 percent value of *t*-distribution, 2.59, and Wald test statistic exceeds 1 percent value of x^2-distribution of 2nd order flexibility, 9.210. From the results of t-test and Wald test, the explanatory variables are enough significant.

Table 2. Results for 362 Cases without Price Spike

		362 cases	
range of suspension		0-3000	0-5000
number of inconsistent cases		37	34
consistent rate R/N		0.8978	0.9061
t-ratio	average $E[Z]$	9.070	9.699
	variance $V(Z)$	-8.856	-9.500
	threshold γ_1	5.422	5.688
	threshold γ_2	7.477	8.515
Wald test statistic		83.261	95.647

Three Level Probit Model for Cases With Spike

The three level ordered probit models for 240 cases with spike and the suspension range up to 3000 and up to 5000 are shown in (15) and (16), respectively.

$$\hat{v} = 3.622 \times 10^{-4} E[Z] - 1.276 \times 10^{-7} V(Z)$$
$$\hat{\gamma}_1 = 1.091, \quad \hat{\gamma}_2 = 2.065 \qquad (15)$$
$$\hat{v} = 3.198 \times 10^{-4} E[Z] - 1.199 \times 10^{-7} V(Z)$$
$$\hat{\gamma}_1 = 0.629, \quad \hat{\gamma}_2 = 2.301 \qquad (16)$$

Moreover, using the results of all 602 cases, the three level ordered probit models with the suspension range up to 3000 and up to 5000 are shown in (17) and (18), respectively

$$\hat{v} = 3.435 \times 10^{-4} E[Z] - 1.028 \times 10^{-7} V(Z)$$
$$\hat{\gamma}_1 = 1.560, \quad \hat{\gamma}_2 = 2.534 \qquad (17)$$
$$\hat{v} = 3.125 \times 10^{-4} E[Z] - 9.556 \times 10^{-8} V(Z)$$
$$\hat{\gamma}_1 = 1.330, \quad \hat{\gamma}_2 = 2.839 \qquad (18)$$

Table 3 shows the results of the ordered probit model composed by 240 cases with spike and all 602 cases. Concerning the ordered probit model composed by 602 cases, some results of UNPV method and the ordered probit model are inconsistent. This occurs mainly for the cases with spike. (As concerning the ordered probit model with the suspension range up to 3000, 27 cases among 65 inconsistent cases are the cases with price spike. As concerning the ordered probit model with the suspension range up to 5000, 26 cases among 60 inconsistent cases are.) However, consistent ratio R/N is exceeds 0.9. Moreover, from the results of t-test and Wald test, the explanatory variables have significance. Therefore, it can be said that the proposed probit model added suspension to execution or rejection of the project shows the decision of the project almost correctly even if the spike is included in the price.

Table 3. Results for 240 cases with spike and all 602 cases

		240 cases		602 cases	
range of suspension		0-3000	0-5000	0-3000	0-5000
number of inconsistent		19	24	65	60
R/N		0.9208	0.900	0.8920	0.9003
t-ratio	$E[Z]$	8.029	9.117	12.407	13.965
	$V(Z)$	-7.389	-8.298	-11.851	-13.131
	γ_1	3.126	2.282	6.618	6.366
	γ_2	5.354	6.153	9.562	10.992
Wald test statistic		64.498	83.223	155.402	197.310

Ordered Probit Model Composed by Small Data

In former section, the ordered probit model is composed by all 602 cases. However, because we often cannot get enough data, we should compose the ordered probit model from small number of data.

To check it, 100 cases are extracted from all 602 cases at random. 100 cases contain 40 cases with price spike. The ordered probit model with the suspension range up to 3000 and up to 5000 are shown in equations (19) and (20), respectively.

$$\hat{v} = 3.849 \times 10^{-4} E[Z] - 1.145 \times 10^{-7} V(Z)$$
$$\hat{\gamma}_1 = 1.576, \quad \hat{\gamma}_2 = 2.745 \qquad (19)$$
$$\hat{v} = 4.132 \times 10^{-4} E[Z] - 1.235 \times 10^{-7} V(Z)$$
$$\hat{\gamma}_1 = 1.680, \quad \hat{\gamma}_2 = 3.418 \qquad (20)$$

Table 4 shows the results of the ordered probit model composed by 100 cases. From the results, consistent ratio R/N is about 0.9. Compared to the results of the ordered probit model composed by 100 cases and all 602 cases, this value is almost similar. Therefore, it can be said that it is possible to compose the ordered probit model from a small data, for example, 100 cases. However, it is future work to clarify how much data is necessary to ensure the accuracy.

Table 4. Results for Small Data (100 cases)

		100 cases	
range of suspension		0-3000	0-5000
number of inconsistent cases		65	55
consistent rate R/N		0.8920	0.9086
t-ratio	average $E[Z]$	4.648	4.986
	variance $V(Z)$	-4.705	-5.006
	threshold γ_1	2.219	2.310
	threshold γ_2	3.552	4.159

Examination of Suspension Range

In this paper, the suspension range of the ordered probit model is assumed to be 2 patterns, that is, between 0 and 3000 and between 0 and 5000. The suspension range is able to be set freely and may evaluate the attitude of investors for the risk.

We examine the suspension range by changing volatility, which is related to the risk. Volatilities of the electric power price and the fuel price, one of the parameters of average regression model, are assumed to be 3.3 and 1.0 respectively as the base case. From the base case, both volatilities are changed by -0.2, +0.2 and +0.4 simultaneously. We simulate 362 cases without price spike for various volatility cases.

Table 5 shows the results of UNPV method. The larger volatility is, the smaller average of UNPV is and the larger variance of UNPV is. This result shows that the risk becomes larger by volatility.

Table 5. Results of UNPV Method

Volatility	Average of UNPV	Variance of UNPV
Base (3.3, 1.0)	-2198.633	4.066×10^8
-0.2 (3.1, 0.8)	994.345	3.838×10^8
+0.2 (3.5, 1.2)	-5213.179	4.386×10^8
+0.4 (3.7, 1.4)	-8205.137	4.460×10^8

Table 6 shows the number of execution, suspension and rejection when the volatilities of electric power price and fuel price are changed. The number of suspension has no significant difference when the volatilities are changed.

Moreover, Table 7 shows the result of the suspension range when the number of the suspension is adjusted to the same numbers, 31 and 44, which are the number of suspension in the base case. There is also no significant difference to the suspension range. However, as the number of suspension is small comparing to the number of total cases, we cannot find the relation between the suspension range and the attitude of investors for the risk clearly. It is our future task to find the relation.

Table 6. Comparison of Decision by Volatilities

suspension range	0-3000		
decision	rejection	suspension	execution
Base	183	31	148
volatility -0.2	162	22	178
volatility +0.2	208	21	133
volatility +0.4	227	26	109
suspension range	0-5000		
decision	rejection	suspension	execution
Base	183	44	135
volatility -0.2	162	38	162
volatility +0.2	208	37	117
volatility +0.4	227	39	96

Table 7. Suspension Range for Same Number of Suspension

number of suspension	31	44
Base (3.3, 1.0)	0 - 3000	0 - 5000
volatility -0.2 (3.1, 0.8)	0 - 4101	0 - 5317
volatility +0.2 (3.5, 1.2)	0 - 3930	0 - 5153
volatility +0.4 (3.7, 1.4)	0 - 3775	0 - 5668

Conclusion

In this paper, we propose three level ordered probit model, in which ternary variable is introduced to represent execution, suspension and rejection of the project. Validity of the proposed three level ordered probit model is verified by applying the project evaluation for gas thermal power plant.

We calculate 362 cases by changing the parameters of average regression model for electric power price and fuel price without price spike and 240 cases with price spike. We compose the three level ordered probit model from 362 cases without price spike, 240 cases with price spike, and all 602 cases. Moreover, we compose the ordered probit model from 100 cases extracted from all 602 cases at random. From the results of t-test and Wald test, the explanatory variables of the ordered probit model composed by all 4 patterns and thresholds have enough significance. The decision of execution, suspension and rejection is consistent with the results of three level ordered probit model and UNPV method at around 90% degree.

Finally, we examine a suspension range by changing volatility. From the results, there is no significant difference to the number of suspension and suspension range. We cannot find the difference as the number of suspension is small comparing to the number of all cases. We will study on it because we think the suspension range may evaluate the attitude of investors for the risk.

The proposed three level ordered probit model can decide execution, suspension and rejection of the project almost correctly. The ordered probit model is considerably effective. In the future, we hope this probit model becomes a useful tool to evaluate the project in electrical industries.

References

[1] L. Clewlow and C. Strickland : "Energy Derivatives Pricing Risk Management", Lacima Group Pty Limited, 2000.Use font 8 for all references.

[2] Y. Miyahara : "Project assessment method based on the expected utility theory", Discussion Papers in Economics, No.446, Nagoya City University, 2006.

[3] H. Miyauchi., K. Miyahara, T. Misawa and K. Okada : "Risk Assessment for Generation Investment Based on Utility Indifference Pricing", CIGRE Osaka Symposium 405, 2007.

[4] T. Misawa : "Simplification of Utility Indifference Net Present Value Method", Discussion Papers in Economics No.509, Nagoya City University, 2009.

[5] N. Hirata, H. Miyauchi and T. Misawa : "Composition of Probit model of simplified UNPV method", 16th International Conference on Electrical Engineering, Busan Korea, 2010.

[6] Japan Electric Power Exchange : http://www.jepx.org/ (*Online available*)

[7] ICE : Global Commodity Markets : http://www.theice.com/ (*Online available*)