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EXPECTED EFFECT OF ENVIRONMENTAL INVESTMENT ON MARKET SHARE OF OIL COMPANY

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This research is aimed at examining a possibility of using environmental investment as an oil company's strategy for increasing its market share. The numeric data of environmental investment and share price in oil market are analyzed with the method of econometrics [1], and then the computer simulation is carried out with the method of system dynamics [2]. Yearly data are collected between 2003 and 2011 from open information sources of 12 major oil companies in 8 countries, on their net incomes, share prices, environmental investments, social investments, the emitted amounts of 4 types of air pollutions, and the volumes of spilled oil into the oceans. Upon the results of the investigations, it is found that there is a possibility that a certain degree of environmental investment may increase the market share of a company; and, there is a possibility for strategic environmental investment, while still increasing the market share.

INTRODUCTION

In the oil industry of the world, the companies' goal is to sell more oil in the market to gain more net income; but, the companies also invest on environmental protections and social development. The purpose of this paper is to indicate the expected effects of the environmental investment to the oil sales. Data are collected between 2003 and 2011 from 12 major oil companies' reports through open information sources, as shown in Table 1, in Brazil, France, Italy, Netherlands, Norway, Russian Federation, the United Kingdom, and the United States of America on their net incomes, share prices, environmental investments, social investments, the emitted amounts of carbon dioxide, sulfur oxides, and methane, as well as the volumes of spilled oil into the oceans. The descriptive statistics of those variables are shown in table 2–3.

Table 1. Selected oil companies for the data analysis

Company	Location of Headquarters	Website
BP	London, England	http://www.bp.com/extendedsectiongenericarticle.do?categoryId=9039692&contentId=7072683
Lukoil	Moscow, Russia	http://www.lukoil.ru/new/finreports/2012
Tatneft	Almetievsk, Tatarstan, Russia	http://www.tatneft.ru/wps/wcm/connect/tatneft/portal_rus/infoactsinvest/otchetnost_po_rsbu/
Total	Tour Total, Paris, France	http://www.total.com/fr/investisseurs-institutionnels/publications/documents-annuels-601405.html
Shell	The Hague, Netherlands	http://www.shell.com/global/aboutshell/investor/financial-information/annual-reports-and-publications/archive.html
ENI	Rome, Italy	http://www.eni.com/en_IT/investor-relation/reports/reports.page?type=bil-rap
Chevron	San Ramon, California, the USA	http://www.chevron.com/news/publications/#b2

Table 1 (*continued*)

Petrobras	Rio de Janeiro, Brazil	http://www.investidorpetrobras.com.br/en/financial-results/
Exxon Mobil	Irving, Texas, the USA	http://ir.exxonmobil.com/phoenix.zhtml?c=115024&p=irol-reportsfinancial
Gazprom	Moscow, Russia	http://www.gazprom.ru/investors/reports/2011/
Rosneft	Moscow, Russia	http://www.rosneft.ru/Investors/statements_and_presentations/annual_reports/
Statoil	Stavanger, Norway	http://www.statoil.com/en/InvestorCentre/AnnualReport/Pages/default.aspx

Table 2. Descriptive statistics of the selected data

Statistics	Net income (million US dollars)	Social investment (million US dollars)	Environmental investment (million US dollars)	NO_X emission (1000 tons)	SO_2 emission (1000 tons)
Mean	13645	197.7	1313	110.5	91.93
Median	12322	132.2	879.8	115.7	74.86
Maximum	45220	784.5	18400	404.0	283.0
Minimum	–3324	6.716	19.57	1.070	1.300
Std. Dev.	9969	186.1	2149	81.80	72.51
Skewness	0.926	1.480	5.243	0.446	0.579
Kurtosis	3.669	4.415	39.23	2.988	2.618
Obs.	108	108	108	108	108

Note : Std.Dev. — standard deviation. Obs. — number of observations.

Table 3. Descriptive statistics of the selected data

Statistics	Methane emission (1000 tons/year)	CO_2 emission (1000 tons/year)	Percentage of female management (%)	Oil spill (Barrel/year)	Water consumption (million m^3)	Share price (US dollars)
Mean	458.0	75550	22.72	13390	189.8	48.96
Median	173.1	63190	22.80	7063	181.8	38.70
Max.	1826	145500	42.54	112900	1015	198.3
Min.	22.16	40850	10.48	276.7	6.000	0.3630
Std.Dev	580.3	27870	7.491	18580	160.3	45.42
Skewess	1.181	1.146	0.659	3.225	2.417	1.422
Kurtosis	2.565	3.070	3.297	16.19	13.48	4.792
Obs.	108	108	108	108	108	105*

Note: Std.Dev. — standard deviation. Obs. — number of observations. Number of the observations for the share price is 105, while others' are all 108, because of 3 missing observations in the share price database.

METHODOLOGY

For the analysis, at first, the correlations [1] are calculated; and, multivariable regression analysis [1] is made to investigate the strength of the relation between the environmental investment and the share price; then the time-series analysis [1] on the share prices is made on selected companies in order to check the continuity share price with the investment. Then, the logic of environmental investment is tested by computer simulation with the method of system dynamics [2].

For the analysis in the econometrics, the share price is considered as a surrogate for the size of market share; and, in the computer simulation of system dynamics, the proportions of the number of companies who take specific strategy in environmental investment are used as the indicator of the market share. The size of market share and the value of share price are not proportional, however when a company increases the sales of its product in a market, leading to the larger market share, the share price also increases because the investors (buyers of the company's stock) wish to buy the company's stock more, leading to the higher share price.

The basic methodology of econometrics [1]. First consider estimating the coefficients of a linear model.

At first, the average value $E(x)$ of each variable x is calculated:

$$E(x) = 1/n \times \sum_{i=0}^{n} x_i ,\ldots, , \tag{1}$$

where $i = 1,2,\ldots,n,$ n is the total number of the sample of the variable, x.

Then, the variance $V(x)$ and covariance $C(x, y)$ of the variables x and y are calculated:

$$V(x) = E(x^2) - E^2(x) = {\sigma_x}^2, \tag{2}$$

$$C(x, y) = E(x^* y^*) = \sigma_{xy} , \tag{3}$$

where $x^* = x - E(x),$ $y^* = y - E(y)$, y is also an independent variable.

Then, a linear regression model is constructed as follows.

In case of 3 independent variables, the regression model is written as the follow:

$$Y = c_1 + c_2 X_2 + c_3 X_3 + c_4 X_4 , \tag{4}$$

where Y is dependent variable, X_j are independent variables, and c_1 and c_j are constant values, where, $j = 2, 3, 4$.

The values of those coefficients are obtained by the following equations, which are obtained by an optimization of $U = Y - (c_1 + c_2 X_2 + c_3 X_3 + c_4 X_4)$ [1].

$$c_1 = E(Y) - c_2 E(X_2) - c_3 E(X_3) - c_4 E(X_4) . \tag{5}$$

$$\begin{aligned} c_2 = {} & \{({\sigma_{X_3}}^2 {\sigma_{X_4}}^2 - {\sigma_{X_3 \cdot X_4}}^2)(\sigma_{X_4 \cdot Y} \sigma_{X_3 \cdot X4} - \sigma_{X_2 \cdot X_4} \sigma_{X_3 \cdot Y}) - \\ & - (\sigma_{X_2 \cdot X_3} \sigma_{X_3 \cdot X_4} - {\sigma_{X_3}}^2 \sigma_{X_2 \cdot X_4})({\sigma_{X_4}}^2 \sigma_{X_3 \cdot Y} - \sigma_{X_3 \cdot X_4} \sigma_{X_2 \cdot Y})\} / \\ & / \{({\sigma_{X_3}}^2 {\sigma_{X_4}}^2 - {\sigma_{X_3 \cdot X_4}}^2)({\sigma_{X_2}}^2 \sigma_{X_3 \cdot X_4} - \sigma_{X_2 \cdot X_3} \sigma_{X_2 \cdot X_4}) - \\ & - (\sigma_{X_2 \cdot X_3} \sigma_{X_3 \cdot X_4} - {\sigma_{X_3}}^2 \sigma_{X_2 \cdot X_4})({\sigma_{X_4}}^2 \sigma_{X_2 \cdot X_3} - \sigma_{X_3 \cdot X_4} \sigma_{X_2 \cdot X_4})\} . \end{aligned} \tag{6}$$

$$\begin{aligned} c_3 = {} & \{({\sigma_{X_2}}^2 {\sigma_{X_4}}^2 - \sigma_{X_2 \cdot X_3} {\sigma_{X_4}}^2)(\sigma_{X_2 \cdot X_3} \sigma_{X_2 \cdot Y} - {\sigma_{X_2}}^2 \sigma_{X_3 \cdot Y}) - \\ & - (\sigma_{X_2 \cdot X_3} \sigma_{X_2 \cdot X_4} - {\sigma_{X_2}}^2 \sigma_{X_2 \cdot X_4})(\sigma_{X_2 \cdot X_4} \sigma_{X_3 \cdot Y} - \sigma_{X_2 \cdot X_2} \sigma_{X_4 \cdot Y})\} / \\ & / \{(\sigma_{X_2 \cdot X_4} \sigma_{X_3 \cdot X_4} - \sigma_{X_2 \cdot X_3} {\sigma_{X_4}}^2)({\sigma_{X_2 \cdot X_3}}^2 - {\sigma_{X_2}}^2 {\sigma_{X_3}}^2) - \end{aligned}$$

$$-(\sigma_{X_2\cdot X_3}\sigma_{X_2\cdot X_4}-\sigma_{X_2}{}^2\sigma_{X_3\cdot X_4})(\sigma_{X_2\cdot X_4}\sigma_{X_3}{}^2-\sigma_{X_2\cdot X_3}\sigma_{X_3\cdot X_4})\}. \quad (7)$$

$$c_4=\{(\sigma_{X_2\cdot X_4}\sigma_{X_3}{}^2-\sigma_{X_2\cdot X_3}\sigma_{X_3\cdot X_4})(\sigma_{X_2\cdot X_3}\sigma_{X_2\cdot Y}-\sigma_{X_2}{}^2\sigma_{X_3\cdot Y})-$$

$$-(\sigma_{X_2\cdot X_3}{}^2-\sigma_{X_2}{}^2\sigma_{X_3}{}^2)(\sigma_{X_2\cdot X_4}\sigma_{X_3\cdot Y}-\sigma_{X_2\cdot X_3}\sigma_{X_4\cdot Y})\}/$$

$$/\{(\sigma_{X_2\cdot X_4}\sigma_{X_3}{}^2-\sigma_{X_2\cdot X_3}\sigma_{X_3\cdot X_4})(\sigma_{X_2\cdot X_3}\sigma_{X_2\cdot X_4}-\sigma_{X_2}{}^2\sigma_{X_3\cdot X_4})-$$

$$-(\sigma_{X_2}.\sigma_{X_3}{}^2-\sigma_{X_2}{}^2\sigma_{X_3}{}^2)(\sigma_{X_2\cdot X_4}\sigma_{X_3\cdot X_4}-\sigma_{X_2\cdot X_3}\sigma_{X_4}{}^2. \quad (8)$$

Correlation coefficients. For the regression model, the independent variables X_i are independent from each other. Therefore, before formulating the model equation (4), the correlation (ρ) between each pair of the variables need to be investigated by the following equation:

$$\rho_j=\frac{C(X_i,X_j)}{\sqrt{V(X_i)}\sqrt{V(X_j)}}=\frac{\sigma_{X_i.X_j}}{\sigma_{X_i}\sigma_{X_j}}. \quad (9)$$

where $i\neq j$.

Fitting of the regression model in the data. After obtaining the correlations ρ and the coefficients, c_1,c_2,c_3 and c_4, the fitting of the model equation (4) on the given data of x_i and Y needs to be investigated by the following procedure:

- Calculate the predicted value of Y (i.e., $\hat{Y}$) with the following equation:

$$\hat{Y}=c_1+\sum_{j=2}^{k}c_jx_j. \quad (10)$$

where $j=2,3,\ldots,K$.

- Calculate the value of R^2 by the following equation:

$$R^2=\frac{\sum_{i=1}^{n}(\hat{Y}_i-\bar{Y})^2}{\sum_{i=1}^{n}(Y_i-\bar{Y})^2}, \quad (11)$$

where $\hat{Y}-1/n\times\sum_{i=0}^{n}x_i$, $i=1,2,\ldots,n$ and n is the total number of the samples of the variable x_i.

The value of R^2 represents the fitting of the model upon the given data, and when $R^2=1.0$, it is the perfect match, while the level of the matching is lower when the value of R^2 is lower. In practice, if $R^2\geq 0.8$, the matching is significant. However, the threshold value depends on the topic and the data of the concerned research question, therefore the values of R^2 need to be considered on the comparative manner.

Basic method of time series analysis [1]. When the number of the observations of a variable y_t in time series t is n, the j-th auto-covariance of y_t is

$$\gamma_j = C(y_t, y_{t-j}), \tag{12}$$

where $j = 0 \pm 1, \pm 2, \pm 3, \ldots, \pm(n-1)$ and $\gamma_0 = C(y_t, y_t) = V(y_t)$.

The j-th autocorrelation is

$$\rho_j = \frac{C(y_t, y_{t-j})}{\sqrt{V(y_t)}\sqrt{V(y_{t-j})}}. \tag{13}$$

The 1st order approximation of the conditional expected value of y_t is

$$E^*(y_t | y_{t-1}) = \alpha + \beta \times y_{t-1}, \tag{14}$$

where

$$\beta = \sum_{t=2}^{n} (y_{t-1} - m^{**})(y_t - m^*) / (n-1) \Big/ \sum_{t=2}^{n} (y_{t-1} - m^*)^2 / (n-1),$$

$$\alpha = (1-\beta) m^*, \text{ and } m^* = \sum_{t=2}^{n} y_t / (n-1), \; m^{**} = \sum_{t=2}^{n} y_{t-1} / (n-1).$$

Method of system dynamics [2]. The system dynamics simulation assumes “costs” and “gains” of strategies. If one company who follows strategy i meets another company who follows strategy j, i the gain will be $r_{i,j}$; while, if $r_{i,j}$ is negative, it will be a loss. The values $r_{i,j}$ are given by the income (U) minus the cost for environmental investment (Ce), and the cost for penalty or recovery actions at accidents (Cp). When a company applies the strategy i at time of t, the average gain $y_i(t)$ is calculated by

$$y_i(t) = \sum_j r_{i,j} p_j(t), \tag{15}$$

where p_i is the proportion (% $\times 100$) of the companies in the market, who follows the strategy i.

The mean gain by all the strategies is calculated by

$$y(t) = \sum_i y_i(t) p_i(t), \tag{16}$$

then, the growth of the subpopulation who follows the strategy i is modeled as proportional to the difference between its average gain $(y(t))$ and the overall mean gain of all strategies $(y(t))$, i.e.

$$F_i(t) = y_i(t) - y(t). \tag{17}$$

Therefore, the relative growth of the strategy is written as the follow:

$$p_i(t + \Delta t) = p_i(t)[1 + \Delta t F_i(t)], \tag{18}$$

then

$$\frac{p_i(t+\Delta t) - p_i(t)}{\Delta t} = p_i(t) F_i(t), \tag{19}$$

$$\lim_{\Delta t \to 0} \frac{p_i(t+\Delta t) - p_i(t)}{\Delta t} = \frac{dp_i}{dt} = p_i F_i . \qquad (20)$$

The relative growth of the proportion of the company with the strategy i is:

$$\frac{dp_i}{dt} = p_i F_i = p_i(y_i - y) = p_i y_i - p_i \sum_k y_k p_k =$$

$$= p_i \sum_j r_{i,j} p_j(t) - p_i \sum_k \sum_j r_{k,j} p_j(t) p_k(t) . \qquad (21)$$

RESULTS

Table 4 shows the correlations between each pair of the variables, which are calculated by the equation (9). The net income has a positive correlation with the share price, and so does the environmental investment; however, the social investment holds a negative correlation with the share price. Fig. 1 also confirms these correlations; however, it is recognized in the figure, that the amount of environmental investment briefly divide the plots of the share price into two groups; and so does the amount of social investment. Upon this observation, the other correlation matrices are made for different groups, i.e. the higher environmental investment, the lower environmental investment, the higher social investment, and the lower social investment. The obtained correlations for these 4 groups are shown in table 5 to table 8.

Table 4. Correlation matrix

Variable	Income	Social	Envi-ronment	Women	NO_X	SO_2	Meth-ane	CO_2	Oil	Water
Income	1									
Social	0.1265	1								
Environment	0.2928	−0.0830	1							
Women	−0.2104	0.2655	−0.0288	1						
NO_X	0.4518	0.0769	0.3032	−0.4766	1					
SO_2	0.6943	−0.0246	0.2415	−0.4392	0.6243	1				
Methane	0.3438	0.7020	0.1382	0.3575	0.2460	0.2179	1			
CO_2	0.4762	0.3077	0.1742	0.1537	0.3471	0.3868	0.7643	1		
Oil	0.2696	−0.0169	0.0129	−0.1686	0.0834	0.3233	−0.0887	−0.0220	1	
Water	0.2739	0.1104	0.1997	−0.3071	0.0851	0.2617	0.0874	0.0048	0.1443	1
Shareprice	0.3871	−0.0408	0.1894	−0.2342	0.0024	0.4117	−0.1923	−0.1390	0.1107	0.1394

Note: Number of observation is 105. INCOME: net income, SOCIAL: social investment, ENVIRONMENT: environmental investment, WOMEN: percentage of female management, NO_X: NO_X emission, SO_2: SO_2 emission, METHANE: Methane emission, CO_2: CO_2 emission, OIL: oil sipll, WATER: water consumption

Table 5. Correlations for higher social investment (>300 million US dollars)

Variable	Income	Shareprice	Social	Women
Income	1			
Shareprice	0.2842	1		
Social	0.1303	−0.7155	1	
Women	−0.3493	−0.5999	0.57312	1

Table 5 and table 6 show that the negative correlation between social investment and the share price is mainly observed in the group of higher social investment, while the group of lower social investment does not indicate negative correlation with the share price. This observation implies that the social investment may not prevent raising the share price up to some degree.

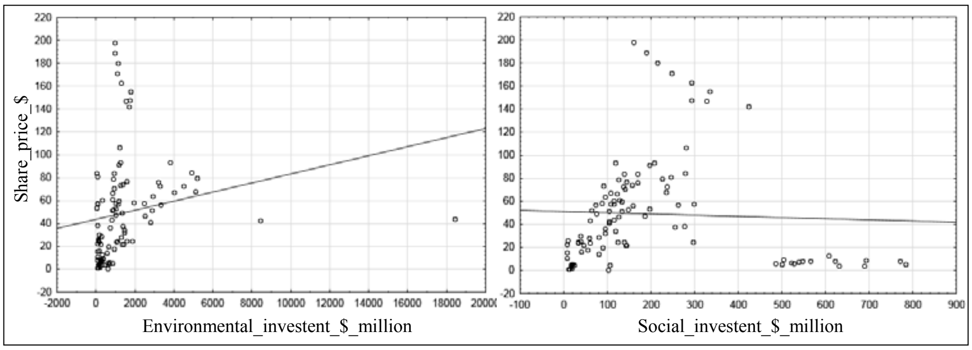


Fig. 1. Relations between share price, environmental investment, and social investment

Table 6. Correlations for lower social investment (<300 million US dollars)

Variable	Income	Shareprice	Social	Women
Income	1			
Shareprice	0.4051	1		
Social	0.5331	0.6323	1	
Women	−0.1732	−0.0963	−0.2902	1

Table 7 and table 8 show that the negative correlation between environmental investment and the share price is mainly observed in the group of higher environmental investment, while the group of lower environmental investment does not indicate negative correlation with the share price. This observation implies that the environmental investment may not prevent raising the share price up to some degree. Table 7 and table 8 also show that the higher environmental investment holds negative correlations with the volumes of emissions of NO_X, SO_2, methane, and CO_2, and the volume of spilled oil, while the lower environmental investment does not. This observation implies that the higher environmental investment may have induced the effect of reducing the pollutions.

Table 7. Correlations for higher environmental investment (> 2000 million US dollars)

Variable	Income	Environment	CO_2	Methane	NO_X	SO_2	Oil	Water
Income	1							
Environment	−0.5483	1						
CO_2	0.6395	−0.2921	1					
Methane	0.6123	−0.2515	0.9598	1				
NO_X	−0.4987	−0.0362	−0.5262	−0.6514	1			
SO_2	0.4938	−0.3964	0.8746	0.7875	−0.1629	1		
Oil	−0.0157	−0.0209	−0.2609	−0.1641	0.1377	−0.3658	1	
Water	0.4893	−0.1665	0.3474	0.4028	−0.3562	0.0678	0.6769	1
Shareprice	0.6660	−0.2883	0.3904	0.4309	−0.3502	0.1471	0.2254	0.6628

Upon the findings above, a model for multivariable regression analysis, as shown in the equation (4), is constructed with the following assumption: the share price is influenced by the net income (company's profit as the result of the oil sales), together with the environmental investment and the social investment.

Table 8. Correlations for lower environmental investment (<2000 million US dollars)

Variable	Income	Environment	CO_2	Methane	NO_X	SO_2	OIL	Water
Income	1							
Environment	0.5496	1						
CO_2	0.1768	−0.1484	1					
Methane	0.0298	−0.2184	0.6403	1				
NO_X	0.4845	0.4462	0.3551	0.2246	1			
SO_2	0.7005	0.5799	0.0950	−0.0739	0.6647	1		
Oil	0.4320	0.2123	0.0274	−0.0727	0.1025	0.4369	1	
Water	0.1346	0.0365	−0.1984	−0.0527	0.0021	0.1965	0.1579	1
Shareprice	0.3933	0.5135	−0.3055	−0.3357	−0.0355	0.4291	0.1167	0.0955

Table 9 shows the results of multivariable regression analysis, which are calculated by the equations from (1) to (8). This result indicates which of the social investment, the environmental investment or the net income, is more influential to the share price. In regard to the value of R^2, which is calculated by the equation (11), the model fittings are good in the groups of the higher environmental investment and the higher social investment, whose value of R^2 is higher than 0.60 in both groups. In the group of the higher environmental investment, the coefficient values indicate that the environmental investment and the net income are less influential than the social investment; while, in the group of lower environmental investment, the environmental investment is 3 times more influential than each of the social investment and the net income.

Table 9. Results of the regression analysis

Case	Coefficients in the formula	R^2	Note
1	Share price = 26.71 + 0.000 × Social investment + 0.0015 × Environmental investment + 0.0017 × Net income	0.1628	All data
2	Share price = 32.07 + 0.1448 × Social investment − 0.0003 × Environmental investment + 0.0004 × Net income	0.6093	For higher environmental investment
3	Share price = 9.883 − 0.0124 × Social investment + 0.0357 × Environmental investment + 0.0011 × Net income	0.2838	For lower environmental investment
4	Share price = 0.4783 − 0.0029 × Social investment + 0.1054 × Environmental investment − 0.0023 × Net income	0.9172	For higher social investment
5	Share price = 9.329 +0.3038 × Social investment − 0.0012 × Environmental investment + 0.0005 × Net income	0.4069	For lower social investment

In the group of the higher social investment, the environmental investment is 3 times more influential than each of the social investment and the net income; while, in the group of lower social investment, the social investment is much more influential than each of the environmental investment and the net income.

The above observation implies that the environmental investment may be effective for gaining larger market share when the level of the investment doesn't exceed a certain degree; and, so may be the social investment.

Then, for investigating the strategy of environmental investment, 3 companies are selected, which are the ExxonMobil and the BP of the group of higher envionmental investment and the Lukoil in the group of lower environmental investment. Fig. 2 shows the changes of annual net incomes, environmental investments and share prices of these companies from 2003 to

2012. In this figure, both the share price and environmental investment look as if they go up and down together. Here, it is noted that the BP made a large-scale accident at the oil rig in the Gulf of Mexico in 2010, and the net income became a negative value,and the environmental investment unusually went up higher.

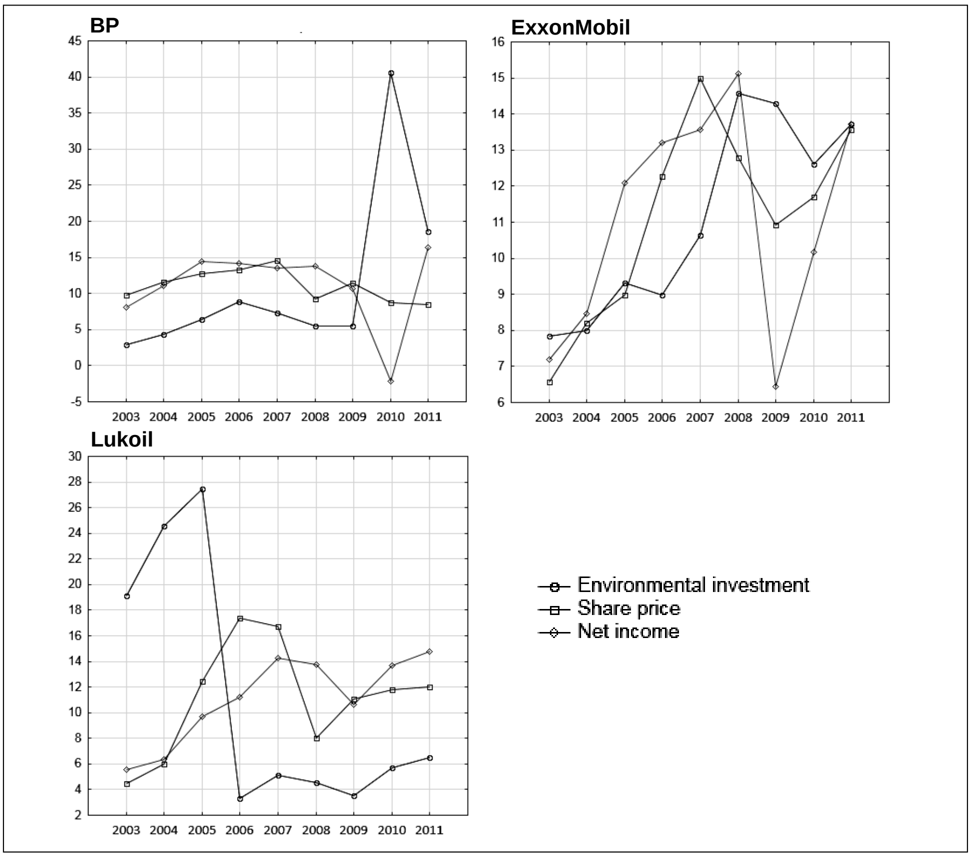


Fig. 2. Oil companies' share price, environmental investment and net income

Results of time series analysis

Upon the observations of Fig. 2, it is also recgnized that the continuities of the movements of these share prices need to be investigated. Then, the values of monthly shareprices of the ExxonMobil and the Lukoil between January 2003 and December 2011 are investigaed with the tequnique of time series forecasting. (Here, the monthly data has been obtained from the open information source of the historical shpare prices [3], but this database doesn't contain the information of environmental investment; therefore, only share prices are analyzed.) The ExxonMoble is an example of the company that is increasing environmental investment, and the Lukoil for the example of reducing environmental investment. Table 10–12 show the matrices of autocorrelations of monthly share price for each of these two companies, which are calculated by the equation (13). In both cases of the ExxonMobil and the Lukoil, the autocorrelation doesn't show strong periodical trends; but, rather the share price changes only gradually. This result implies that the relation with the environmental investment might not be found in time seriese even if monthly data of the environmental investment were obtained.

Table 10. Autocorrelations of ExxonMobil's monthly changes of share price

Shift	*t*	*t* − 1	*t* − 2	*t* − 3	*t* − 4	*t* − 5	*t* − 6	*t* − 7
t	1							
t − 1	0.9626	1						
t − 2	0.9290	0.9641	1					
t − 3	0.8949	0.9326	0.9658	1				
t − 4	0.8740	0.9023	0.9369	0.9680	1			
t − 5	0.8474	0.8808	0.9067	0.9396	0.9693	1		
t − 6	0.8205	0.8529	0.8854	0.9105	0.9434	0.9712	1	
t − 7	0.7921	0.8259	0.8581	0.8898	0.9158	0.9467	0.9722	1

Note: t−1 means the 1st autocorrelation; t-2 is the 2nd autocorrelation; and so forth.

Table 11. Autocorrelations of Lukoil's monthly changes of share price

Shift	*t*	*t*–1	*t*–2	*t*–3	*t* − 4	*t* − 5	*t* − 6	*t* − 7
t	1							
t − 1	0.8836	1						
t − 2	0.7609	0.8826	1					
t − 3	0.6355	0.7596	0.8818	1				
t − 4	0.5387	0.6327	0.7575	0.8813	1			
t − 5	0.4634	0.5358	0.6280	0.7546	0.8802	1		
t − 6	0.3841	0.4625	0.5334	0.6268	0.7554	0.8807	1	
t − 7	0.3106	0.3820	0.4585	0.5310	0.6259	0.7562	0.8810	1

Table 12. Gains and loss of the companies at the market $(r_{i,j})$

Company	A	B	C
A	$U/2-Ce$, $U/2-Ce$	0, U	$(0+(U/2-Ce))/2$, $(U+(U/2-Ce))/2$
B	U, 0	$(U-Cp)/2$, $(U-Cp)/2$	$((U-Cp)/2+U)/2$, $((U-Cp)/2+0)/2$
C	$(U+(U/2-Ce))/2$, $(0+(U/2-Ce))/2$	$((U-Cp)/2+0)/2$, $((U-Cp)/2+U)/2$	$U2$, $U/2$,

Note: In each cell, the left of the comma is for the company's type in the row, and the right is for the column.

Fig. 3 shows the actual plots of the monthly share prices of these 2 companies over 108 months together with calculated curves of the share prices. The calculated curves are upon the equation (14), which is for the first order forecasting; because, the first order forecasting is enough and the first autocorrelation holds the largest value in the autocorrelation matrices, and also neither does it indicate any periodical trends. The calculated curves imply that the company of increasing environmental investment, the ExxonMobil, holds the upward sloping; while the growth of the share price of the Lukoil doesn't increase.

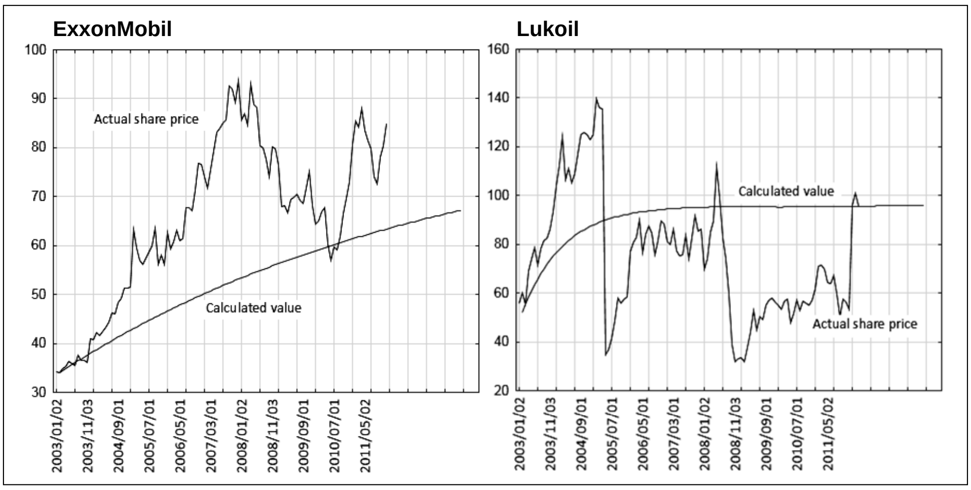


Fig. 3. The first order forecasting of share prices for ExxonMobil and Lukoil (US dollars)

Results of computer simulation by system dynamics

Upon the results of the investigations reported above, it is found that there is a possibility that a certain degree of environmental investment may increase the market share of a company; however, the time series investigation doesn't identify the chronological changes that are supposed to be made by the investment. Therefore, instead of the time series analysis, chronological changes are simulated by logic and procedure of system dynamics [2], which is shown in the equations from (15) to (21).

For the computer simulation, the following logic is made: there are 3 types of the companies, A, B, and C, with net income (U), cost for environmental investment (Ce) and penalty or cost for recovering accident (Cp) for each company's strategy.

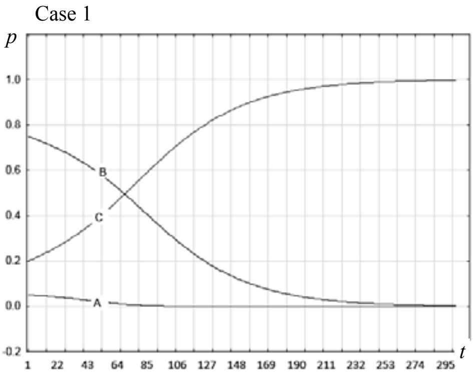
- Company A always minds environment, and takes the best possible actions to reduce the emissions, and waits until its competitor fails in the market.
- Company B never minds environment, and always tries to take over the market from the competitors until it gets accident or penalty.
- Company C always minds environment, and takes the best possible efforts to reduce the emissions, but emits the pollutions only when it meets a serious/strong competitor at the market.

For example, when C meets A in the market, there are 2 equal possibilities.

- If C holds the clients of the market, it keeps the net income (U) and A takes nothing (0).
- If A hold the clients of the market, both have to wait until one of them gives up by only paying the cost of environmental investment (Ce), and then one of them gets the income (U) with equal possibility. So the expected outcome of this case is $U/2-Ce$ for both of them.
- Thus, the overall outcome is $(U+(U/2-Ce))/2$ for C, and $(0+(U/2-Ce))/2$ for A.

Thus the gains/loss of the companies $(r_{i,j})$ in their meetings are as shown in Table 12.

Case	Strategy	p_i	U	Ce	Cp
1	A	0.05	1.00	0.10	1.20
	B	0.75			
	C	0.20			
2	A	0.05	1.00	0.20	1.20
	B	0.75			
	C	0.20			
3	A	0.05	1.00	0.30	1.20
	B	0.75			
	C	0.20			



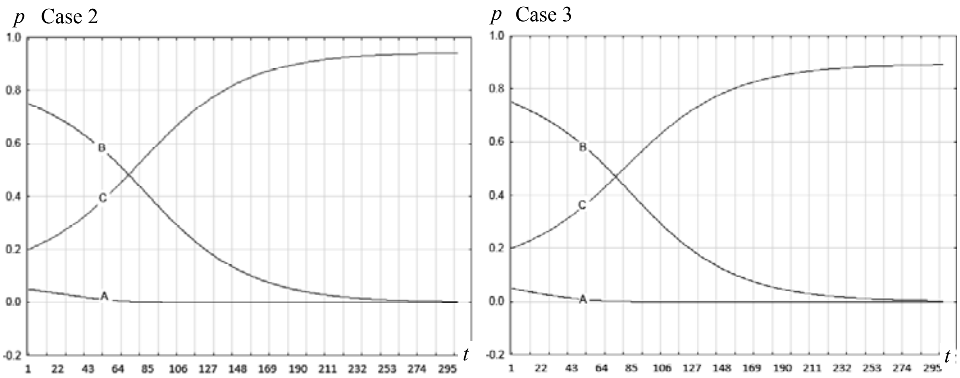


Fig. 4. Initial conditions and the results of computer simulation

Upon the above logic, the chronological changes of the proportion $(p_i$, i.e. p_A, p_B, and $p_C)$ of 3 types of the companies are calculated by the equation (21), which hold 3 different types of strategies respectively. The initial conditions (when $t=0$) for p_i, U, *Ce*, and *Cp* are shown in Fig. 4 together with the results of the calculations. On the simulation, 3 cases are made in accordance to the difference of the initial conditions. The case 1 assumes 0.05 for the proportion of the company type A, 0.80 for the type B, and 0.15 for the type C when $t=0$. These proportions for the case 1 are set, after observing Fig. 5, in which each point on the horizontal axis represents one company of one year and the vertical axis shows the ratio of environmental investment and net income of each company of each year. In Fig. 5, it is observed that 25 percent of the companies invest more than 10 percent of their incomes for the environmental issues, and about 5 percent invest more than 20 percent of the net income. For the simulation, the top 5 percentile are assumed to be the type A, and the second 20 percent are the type C, and the rest are the type B. Meanwhile, in the year of the oil spill accident of the BP in 2010, the net income was reduced almost 120 percent in comparison with the previous years', and the expenditures for the environmental issues increased 7 times as much as in the previous years. From this observation, the simulation assumes 1.20 as the cost of the accident (Cp), while the net income (U) is 1.0. About the cost of environmental investment (Ce), 3 cases are simulated, i.e. 0.1, 0.2 and 0.3, which are selected from Fig. 5. The number of steps (*t*) calculated in this simulation is 302.

The results of the simulation show that the type A and the type B strategies will lose the market share gradually, while the type C strategy increases the market share. In all 3 cases, the share of the type C exceeds the type B's; but, the timing of the type C exceeding the type B will be delayed when the cost of environmental investment becomes larger. This observation shows a similarity with the observation at the econometrics analysis, in which the environmental investment and the higher share price have correlations as long as the investment doesn't exceed a certain level.

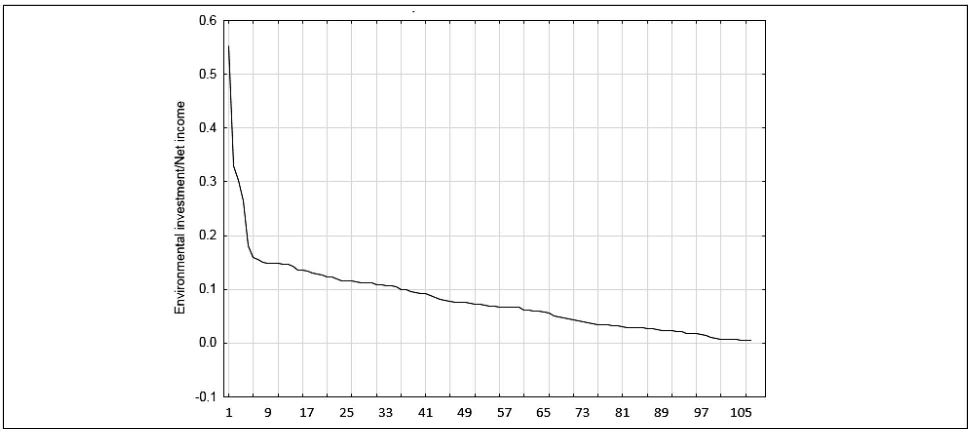


Fig 5. Ranking of the companies in environmental investment vs. net income

CONCLUSIONS AND RECOMMENDATIONS

At first, the correlations and multivariable regression analysis were made to investigate the strength of the relation between the environmental investment and the share price; then the time-series analysis on the share prices is made on selected companies. Upon the results of these investigations, it is found that there is a possibility that a certain degree of environmental investment may increase the market share of a company; and then, computer simulation was carried out with the method of system dynamics to test the logic of the investment strategy. The results indicate that there is a possibility for strategic environmental investment, while still increasing the market share.

The results of the analysis by the econometrics and the computer simulation both show that the strategy of environmental investment may increase the market share as long as the investment is made up to a certain degree, with the presence of rival companies in the same market. However, the simulation is not for the real time, but it is purely for the investigation of the logic and the strategy; therefore, definitive results of the decision making is not obtained yet. Further researches are needed on the topic.

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