A Study of Environmental Management Investment Allocation

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Abstract

The 21st century is a new century of environmental protection. Environmental protection is one of the most important subject matters yet to come. Moreover, as the public pays more attention to environmental problems, enterprises should increase their investment in environmental management. Therefore, determining the investment level for environmental management and allocating the investment to associated environmental management activities has become a major task. The principal and agent theory and sales response functions are used for analysis in this research. The allocation of capital investment in environmental management is found to have significant impact on the aggregate sales response, aggregate profit and investment level. Therefore, in preparing the budget for environmental management, enterprises should focus on investment allocation decisions, determine the investment level and allocation method using integrated means, and apply submarket data in the allocation decision-making process. In other words, in setting the investment level, executive management should take managers' willingness into consideration. In allocating capital investment, managers should identify the optimal allocation method based on submarket characteristics.

Key Words: Environmental Management, Investment Allocation, Principal and Agent Theory

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1. Introduction

As the environment becomes worse, environmental problems have attracted more public attention. This has caused enterprises to take action on environmental protection, for instance, reducing industrial wastes and preventing pollution. With ever-increasing environmental protection awareness enterprises are under great pressure. Therefore, environmental issues are corporate issues because environmental issues will certainly affect corporate development, and even determine the future of the company. Consequently, enterprises must implement environmental management. However, in the capital investment decision making process for environmental management, whether the method employed could generate the optimal result is the motive of this research. In this research, we will conduct an in-depth study of the investment level and investment allocation for environmental management aiming to determine the appropriate investment decisions for enterprises in environmental management.

We applied the Principal and Agent theory developed by Tirole (1988) and Laffont and Tirole (1993) in this research to analyze the environmental management investment level. Using this method, we can learn how corporate internal organizational efficiency and market competition influence environmental management investment level and develop a testable behavioral proposition to make up for the shortfall in insufficient analysis using theories and models in the relevant environmental management literature. In short, the objectives of this research include: (1) The appropriateness of allocating investment in environmental management using a fixed ratio; (2) The appropriateness of preparing the budget for investment in environmental management using a top-down method; (3) Recommending appropriate investment environmental management decisions and the establishment of relevant behavioral proposition by constructing agent theoretical model and sensitivity analysis.

2. Literature Review

2.1 Environmental Management

Even though the environmental protection trend has caused many corporate crises, crises are always accompanied by opportunities. Therefore, the environmental strategy adopted by enterprises determines whether the crisis can be converted into an opportunity. Environmental management is the environmental strategy that has been actively promoted by governments recently to replace the previous end control strategy. The main purpose is to encourage industries to proactively plan for pollution prevention and constantly improve through environmental management to increase environmental protection corporate performance and operational efficiency and thus improve corporate constitution and realize the goal of continuous operation.

2.1.1 Definition of Environmental Management

Winn and Roome (1993) believed that environmental management is the management of the challenges that products, processes and organizations cause to nature, the ecology and cultural systems. Kalassen and McLaughlin (1996) stated that in terms of a product's life cycle, environmental management refers to the effort to minimize the environmental challenges from business products. Chen (1997) defined environmental management as the attitude, procedure and actions that enterprises take to handle the challenges to the natural ecological environment caused directly or indirectly caused by corporate operational activities. According to Global Environmental Management Initiative (GEMI), environmental management can be divided into five levels (Yang, 1996). Based on the above, we believe, in this paper, that environmental management refers to all of the activities that are intended to minimize the challenges that corporate operational activities impose on the environment from the perspective of the product life cycle by integrating corporate resources and a systematic approach to reduce this negative impact.

2.1.2 Benefits of Environmental Management

Implementing environmental management can bring many tangible and intangible benefits to enterprises. Taylor (1992), Tibor and Feldman (1997) and Lu (1997) proposed that the benefits from implementing environmental management, to environmental protection corporate performance, include reducing pollution, improving the effectiveness of pollution prevention and increasing corporate environmental performance. This extends to corporate financial performance, including cost savings, increasing market profitability, improving corporate financial performance and further attracting capital investment and reducing industry insurance premiums. With the ever-increasing awareness of environmental protection and stricter public requirements for environmental protection, we believe that environmental management will bring enterprises more tangible and intangible benefits.

2.2 Related Literature

In this section, we will conduct a complete review and analysis of both the foreign and domestic literature relating to environmental management to understand the research direction of existing scholars and the future development of environmental management.

2.2.1 Green Marketing and Sales

Most of the literature relating to green marketing focuses on the marketing strategy about how enterprises fulfill their professional ethics and marketing morals in response to environmental protection requirements, or consumer behavior with regard to purchasing green products. The researches done by Gao and Hu (1995), Huang and Xiao (1995), and Menon and Menon (1997) etc are an example.

2.2.2 Environmental Accounting

Accounting and financial systems are vital to every company's operations. The objective of accounting is to provide accurate information to facilitate investment and credit decision-making. Therefore, when the public requirements for environmental protection increase, naturally, the concept of environmental protection must be included in the accounting and financial systems. For instance, financial statements start to reflect environment-related expenses, hence, environmental accounting or green accounting comes into shape. Environmental investment assessment primarily means that investment decision-making and investment assessment should take the environment into consideration. Selg (1994) proposed that the environmental factors considered should include the recognition and measurement of environmental costs, time value of currency, cash flow and profitability, and quantitative and qualitative data analysis etc.

2.2.3 Performance Evaluation

The domestic researches regarding the environmental management performance evaluations are oriented toward the establishment of environmental performance indexes. Companies stressing environmental protection founded a "Green Business Forum" and started a research plan for "Enterprise Environmental Management Index" in 1996. This research targeted 500 large manufacturers and 250 large service companies in Taiwan for a wide-spread survey and study. The survey results showed that a bottleneck incurred in implementing environmental management and protection by domestic companies and the distance to international environmental protection standards. In addition, based on an assessment of the answers provided by the companies under survey to various question items on environment management and environmental protection, an environmental protection index evaluation table was established for Taiwanese companies in this research. We believe that the establishment of such corporate environmental indexes can help businesses with actual implementation and continuous improvement of environmental protection (Green Business Forum, 1997).

2.3 The Principal and Agent Theory

The Principal and Agent theory (Gao and Hu, 1995) is in fact, a game theory. In this theory, asymmetrical information is a rather important feature. Therefore, it is appropriate to apply the theory to handling moral hazard. If, after the buyer and the seller reach an agreement, either party (e.g. the buyer) of the transaction takes an action, which will affect the other party of the transaction but impossible for the affected party to notice, then the affected party is considered as facing moral hazard. We believe that moral hazard may occur in investment decision-making. The senior executives do not have the detailed information about an individual submarket when making investment decisions. Instead, only the managers have the detailed information about individual submarkets. The submarket is relative to the aggregate market. The aggregate market consists of various submarkets.

2.4 Consumers' Sales Response Function

According to the relevant literature, investing in environmental management is positively related to the financial performance of enterprises. Of course, profit is most representative of the financial performance of enterprises. As a result, the relationship between financial performance and environmental investment is studied from the viewpoint of profit in this paper. However, profit is the total income deducted by total cost and total income closely correlates to sales. Hence, in this paper, a sales response function is adopted to express the degree to which the consumers acknowledge corporate environmental investment performance. Consequently, the higher the degree of acknowledgment, the greater the response as reflected in sales revenue and vice versa.

$$Q = a(1 - e^{bX});\ a,\ b,\ c > 0 \tag{2-1}$$

Where Q represents the sales revenue for a period of time, X represents the environmental management investment level, a, b, c are coefficients. In this function, if $X = 0$, c amount of sales revenue will be realized without any investment in environmental management, that is, the potential sales on the market. The saturation level is $a + c$, accompanied by decreasing returns to scale. Hence, the sales response function beyond saturation is represented by:

$$Q = a + bX + cX^2;\ c < 0,\ Q > 0 \tag{2-2}$$

By nature, the above two sales response functions are certain. However, in the behavioral model, uncertainty (speculation) may exist. The simple linear regression model, with the addition of error item (ε), can be applied to the uncertain sales response function and the function is rewritten as:

$$Q = a + bX + \epsilon \tag{2-3}$$

Where Q still represents the sales revenue for a period of time, X represents the environmental management investment level, a, b are coefficients. The above three sales response functions are used in this paper to analyze the investment allocation for environmental management and compare environmental management investment decisions using the principal and agent relative to their risk aversion.

3. Environmental Investment Allocation Model Analysis

First of all, we will brief you on the submarket sales response functions. The submarket sales characteristics can be represented by two types of market response functions; a concave saturation sales response function and beyond saturation sales response function. The decision by agent allocation rule assumes that the principal authorizes the agent a certain investment level, under which the agent uses fixed-ratio allocation and optimal allocation, respectively, to allocate the investment to individual submarkets and compares the changes in these allocation rules when the investment level rises. Value simulation is performed to illustrate and emphasize the different results from fixed-ratio allocation and optimal allocation by setting appropriate submarket response coefficients, that is, the effect that different allocation rules have on aggregate sales and profit.

3.1 Concaved-Saturation Response Function as the Sale Characteristic of Submarkets

The basic assumptions in this section are: the aggregate market facing enterprises is comprised of two submarkets; the environmental investment decision is made for a period of time, for example, annual environmental management budget; the environmental investment in previous periods does not have any delayed effect; no cross effect of allocation is assumed between submarkets, that is, submarkets are independent of each other; in addition, all the other market environmental factors including market price and production conditions (manufacturers' marginal cost) are assumed constant.

3.1.1 Sales Response Function

The aggregate market is comprised of two submarkets, where i = 1, 2 represent submarket 1 and 2, respectively; s_i represents current sales response (dollar amount/period). Hence, the sales response function for the investment level x_i (dollar amount/period) of environmental management when allocated to submarket i is:

$$s_i = \alpha_i + \beta_i[1 - \exp(-\gamma_i x_i)], \quad i = 1, 2 \tag{3-1}$$

Where coefficient β_i is the market efficiency factor of investment x_i, that is, the potential market sales scale with environmental investment effort. The γ_i represents effective investment factor or conversion factor of environmental management. The $\gamma_i x_i$ represents effective investment amount in environmental management. The saturation level of this function is $\alpha_i + \beta_i$. Using this function, with no investment in environmental management, that is, when the investment in environmental management is zero, the sales amount is α_i.

3.1.2 Allocation Rule Determination

Assume that for a budgeted period of time, the principal is given an investment level R (amount/period) of environmental management. We can see that many agents follow the simple ratio rule to determine the investment allocation to submarkets, that is, when $R > 0$, these allocations can be represented by $(\hat{x}_1, \hat{x}_2)$:

$$\hat{x}_i = w_i R,\ \sum_{i=1}^{2} w_i = 1,\ 0 < w_i < 1,\ i = 1,\ 2 \tag{3-2}$$

In Formula (3-2), w_i is the fixed investment ratio or "allocation weight." Assume that when market information is insufficient, the agent will use a fixed ratio to allocate the investment level of environmental management.

When R is fixed, maximize $C = mS$, and then through (3-3), solve x_i^*. Where m is the gross margin with a range of $0 < m \leqq 1$.

$$\max C = m \sum_{i=1}^{2} \alpha_i + \beta_i [1 - \exp(-\gamma_i x_i)] \tag{3-3}$$

subject to

$$x_1 + x_2 \leq R;\ x_i \geq 0 \text{ for } i = 1,\ 2.$$

By marginal analysis, the optimal allocations for individual submarkets are:

$$x_1^* = [1/\gamma_1 + \gamma_2][\gamma_2 R + \ln(\beta_1 \gamma_1 / \beta_2 \gamma_2] \tag{3-4}$$

$$x_2^* = [1/\gamma_1 + \gamma_2][\gamma_1 R + \ln(\beta_2 \gamma_2 / \beta_1 \gamma_1] \tag{3-5}$$

3.1.3 Comparison of Optimal Allocation and Constant Proportion Investment Allocation

From Formula (3-4) and (3-5), the optimal allocation is equivalent to the constant proportion investment (CPI) allocation only when the marginal responses are equal, that is, $\beta_1 \gamma_1 = \beta_2 \gamma_2$. In this case, CPI has a special allocation weight $w_i = \beta_i / (\beta_1 + \beta_2)$, $i = 1,\ 2$. The investment level is denoted by R_0, that is,

$$R_0 = (1/\gamma_1) \ln(\beta_1 \gamma_1 / \beta_1 \gamma_1) \tag{3-6}$$

3.1.4 Aggregate Effect of Resource Allocation Decision

Now, we take the principal's standpoint and focus on the relationship between the aggregate sales and environmental investment effort. The aggregate sales response function of the CPI allocation is denoted by $\hat{g}(R)$, that is,

$$\hat{g}(R) = \alpha_1 + \beta_1[1 - \exp(-\gamma_1 w R)] + \alpha_2 + \beta_2[1 - \exp(-\gamma_2(1-w)R)] \tag{3-7}$$

Where w is the fixed investment ratio with a range of $0 < w < 1$. The optimal value of the aggregate sales response function is denoted by $g^*(R)$, that is,

$$g^*(R) = \alpha_1 + \beta_1[1 - \exp(-\gamma_1 x_1^*(R))] + \alpha_2 + \beta_2[1 - \exp(\gamma_2 x_2^*(R))] \tag{3-8}$$

3.1.5 Value Simulation

Two cases will be discussed below to compare CPI allocation and optimal allocation.

3.2 Case I

Assume that the submarket's sales response coefficients are $\beta_1 > \beta_2$ and $\gamma_1 = \gamma_1 = \gamma$. Also, assume that the agent uses 50 : 50 CPI rule, that is, when $R > 0$, from (3-7), the following can be derived:

$$\hat{g}(R) = \alpha_1 + \alpha_2 + (\beta_1 + \beta_2)[1 - \exp(-0.5rR)] \tag{3-9}$$

However, if the value of $\hat{\pi}(R)$ is maximized when $R = \hat{R}$,

$$\hat{R} = (2/\gamma)\ln\{[m\gamma(\beta_1 + \beta_2)]/2\} \tag{3-10}$$

In the case of optimal allocation for investment, when $R > R_0 = (1/\gamma)\ln(\beta_1/\beta_2)$, from (3-8), the following can be derived:

$$g^*(R) = \alpha_1 + \alpha_2 + (\beta_1 + \beta_2) - 2(\beta_1\beta_2)^{1/2}\exp(-0.5rR) \tag{3-11}$$

Now, $\pi^*(R)$ is maximized. Note: when $R < R_0$, $g^*(R)$ reflects the sales response function of submarket 1 only.

$$R^* = (2/\gamma)\ln[m\gamma(\beta_1\beta_2)^{1/2}] \tag{3-12}$$

In comparing (3-10) and (3-12), $[(\beta_1 + \beta_2)/2] > (\beta_1\beta_2)^{1/2}$ is obtained; hence, $\hat{R} > R^*$. Based on this case, applying CPI rule to environmental investment allocation will cause excess aggregate investment in environmental management to the principal.

3.3 Case II

A set of reasonable submarket sales response coefficients will be presumed below for value simulation and sensitivity analysis. Assume equal efficiency factors for submarkets, and equal sales responses without any investment effort. Consequently, when applying 50:50 CPI rule, the following can be derived from the earlier analyis,

$$\hat{g}(R) = 1200 - 500[\exp(-0.025R) + \exp(-0.005R)] \quad (3\text{-}13)$$

Through the marginal analysis by profit formula $\hat{\pi}(R) = g\pi(R) - R$, the investment level is calculated to be $\hat{R} = 201$ when $\hat{\pi}(R)$ is maximized. The optimal aggregate sales response function is:

$$g^*(R) = 1200 - 500(1.569)\exp(-0.00833R) \quad (3\text{-}14)$$

Table 1 and Table 2 show the comparison between optimal allocation and CPI allocation as follows:

Table 1. Comparison of Optimal Allocation and CPI Allocation

	Optimal Investment (R)	Aggregate Sales Response Elasticity of Optimal Investment E(R)	Submarket (i)	R^*'s Submarket Allocation $x_i(R^*)$	$\hat{R}$'s Submarket Allocation $x_i(\hat{R})$	R^*'s Aggregate Sales $g(R^*)$	$\hat{R}$'s Aggregate Sales $g(\hat{R})$	R^*'s Aggregate Profit $\pi(R^*)$	$\hat{R}$'s Aggregate Profit $\pi(R^*)$
Optimal Allocation	225	0.211	1	64[a]	60	1080	1053	855	851.9
			2	161[a]	140.7				
CPI Allocation	201	0.198	1	112.5	100.5	1054	1013.7[b]	829	812.7[c]
			2	112.5	100.5				

Note: [a] Under these allocations, the sales elasticity of submarkets is 0.113 and 0.322.
[b] Under $g^*(R)$, approximately $R \fallingdotseq 172.6$.
[c] Under $\pi^*(R)$, approximately $R \fallingdotseq 137$.

According to the analysis results in this section, it is a rare case that CPI allocation happens to be optimal allocation. More often, CPI allocation may lead the principal to incorrect optimal investmetn level. In other words, CPI allocation can't generate the maximal profit.

Table 2. The Relationship between the Profit Differential and Coefficients of CPI Allocation and Optimal Allocation (Concaved-Saturation)

Coefficient	Range	Relationship to Profit Differential
Submarket 1's Environmental Management Effective Investment Factor(r_1)	$0 < r_1 < 0.02$	-
	$r_1 > 0.02$	+
Submarket 2's Environmental Management Effective Investment Factor(r_2)		-
Submarket 1's Market Investment Efficiency Factor(β_1)		-
Submarket 2's Market Investment Efficiency Factor(β_2)		+

3.2 Beyond-Saturation Response Function as the Sales Characteristic of Submarkets

The basic assumptions in this section are: the aggregate market is comprised of two submarkets; all the other environmental factors including market price and production conditions (manufacturers' marginal cost) are assumed constant. In addition, the investment will affect the sales for the same period only, that is, the environmental investment does not have any delayed effect. Lastly, a set of reasonable submarket sales response coefficients are presumed for a simple simulation and sensitivity analysis in the hope for further understanding of the differences resulting from the different allocations adopted by the agent.

3.2.1 Sales Response Function

The sales response function in this section is

$$s_i = a_i + b_i x_i + c_i x_i^2 + \rho x_1 x_2, \ i = 1, 2 \tag{3-15}$$

Where i = 1, 2 indicates that the aggregate market is comprised of two submarkets of 1 and 2; s_i represents the current sales response (dollar amount/period); coefficient a_i means that when $x_i = 0$, that is, with no investment, the sales revenue is a_i; ρ represents cross-effect factor and implies a complementary relationship when $\rho > 0$.

3.2.2 Determination of Allocation Rule

As shown in Section 3.1.2, CPI rule is represented by $(\hat{x}_1, \hat{x}_2)$ when R > 0, e.g. Formula (3-2). When the agent uses the information about the submarket's potential sales scale, the allocation weight w_i is made $w_i = \{\beta_1/(\beta_1+\beta_2)\}$, i = 1, 2; β_i indicates the sales potential of submarket i; to be fair, the agent may set w_i = 1/2 etc. By the same token, through Formula

(3-16), x_i^* can be computed, that is,

$$\max C = m\sum_{i=1}^{2}(a_i + b_i x_i + c_i x_i^2 + \rho x_1 x_2) \tag{3-16}$$

subject to

$$x_1 + x_2 \leqq R;\ x_i \geqq 0 \text{ for } i = 1, 2.$$

Where m is the gross margin with a range of $0 < m \leqq 1$; applying marginal analysis to obtain the optimal allocation for individual submarkets:

$$x_1^* = [b_2 - b_1/2(c_1 + c_2 - 2\rho)] + [c_2 - \rho)/(c_1 + c_2 - 2\rho)]R \tag{3-17}$$

$$x_2^* = [b_1 - b_2/2(c_1 + c_2 - 2\rho)] + [c_1 - \rho)/(c_1 + c_2 - 2\rho)]R \tag{3-18}$$

Moreover, for the maximal value, the second-degree differentiation must be smaller than 0, so $c_1 + c_2 - 2\rho < 0$.

3.2.3 Comparison of Optimal Allocation and CPI Allocation

From Formula (3-17) and (3-18), when $b_1 = b_2$, the CPI allocation is equal to the optimal allocation. In this case, CPI has a special allocation weight $w_i = (c_i - \rho)/(c_1 + c_2 - 2\rho)$, i = 1, 2. When $b_1 \neq b_2$, if $b_1 > b_2$, x_1^* and x_2^* will both be positive only when $R > R_0$. Formula (3-19) is then

$$R_0 = b_2 - b_1/2(c_1 - \rho) \tag{3-19}$$

3.2.4 Aggregate Effect of Investment Allocation Decision

Now we will again use the aggregate sales response function. The aggregate sales response function for the CPI allocation can be represented by $\hat{g}(R)$, that is,

$$\hat{g}(R) = a_1 + b_1(wR) + c_1(wR)^2 + a_2 + b_2[(1-w)R] + c_2[(1-w)R]^2 + 2\rho(wR)[(1-w)R] \tag{3-20}$$

The optimal allocation can be represented by $g^*(R)$, that is,

$$g^*(R) = a_1 + b_1 x_1^* + c_1(x_1^*)^2 + a_2 + b_2 x_2^* + c_2(x_2^*)^2 + 2\rho x_1 x_2 \tag{3-21}$$

Where x_1^* and x_2^* are obtained from Formula (3-17) and (3-18), and R must exceed the critical point R_0. From Formula (3-19), if $R < R_0$, then $x_1^* = R$, $x_2^* = 0$ (now assume $b_1 > b_2$), the aggregate profit function is $\pi^*(R) = mg^*(R) - R$. In addition, by the same token, when the profit function realizes its miximimal value, then $c_1 c_2 > \rho^2$.

3.2.5 Value Simulation

A simple value simulation is done with a set of reasonable submarket sales response coefficients to compare CPI allocation and optimal allocation. In this section, assume $b_1 > b_2$ and $a_1 = a_2$. Since Formula (3-15), (3-20) and (3-21) should all realize their maximal values, the second-degree differentiation must be less than 0, that is, all of the conditions of $c_1 < \rho$, $c_2 < \rho$, $c_1 + c_2 + 2\rho < 0$ and $c_1 c_2 > \rho^2$ should be satisfied. Hence, use the same 50:50 CPI rule, the following can be derived from (3-20):

$$\hat{g}(R) = 200 + 15R - R^2 \tag{3-22}$$

Switching to the optimal allocation rule, when $R > R_0$, the optimal aggregate sales response function is

$$g^*(R) = 203.125 + 17.5R - 0.5R^2 \tag{3-23}$$

Table 3 shows the comparison between optimal allocation and CPI allocation as follows:

Table 3: Comparison of Optimal Allocation and CPI Allocation

	Optimal Investment (R)	**Aggregate Sales Response Elasticity of Optimal Investment E(R)**	**Submarket (i)**	**R^*'s Submarket Allocation $x_i(R^*)$**	**$\hat{R}$'s Submarket Allocation $x_i(\hat{R})$**	**R^*'s Aggregate Sales $g(R^*)$**	**$\hat{R}$'s Aggregate Sales $g(\hat{R})$**	**R^*'s Aggregate Profit $\pi(R^*)$**	**$\hat{R}$'s Aggregate Profit $\pi(\hat{R})$**
Optimal Allocation	16.5	0.0464	1	13[a]	5.875	355.75	301.125	339.25	294.125
			2	3.5[a]	1.125				
CPI Allocation	7	0.0273	1	8.25	3.5	175.25	256[b]	158.75	249[c]
			2	8.25	3.5				

Note: [a] Under these allocations, the sales elasticity of submarkets is 0.372 and 0.0977.
[b] Under $g^*(R)$, approximately $R \fallingdotseq 3.34$ or 31.66.
[c] Under $\pi^*(R)$, approximately $R \fallingdotseq 3.065$ or 29.935.

From Table 3, even if the investment level is $R = \hat{R}$, the aggregate profit can increase by 17.6% through optimal allocation. As a matter of fact, if optimal allocation is applied, the level of $\hat{\pi}(\hat{R})$ can be reached when $R \fallingdotseq 3.065$, that is, $\hat{R}$ can be reduced by 56.2%. From this section, we have learned that the optimal allocation and CPI allocation results are quite different. Only optimal allocation can make the investment in environmental management more efficient. Based on the analysis in this section, we discovered that the chance for CPI allocation to concurrently be the optimal allocation is thin. As R increases, the submarket investment does not increase proportionately, which is even more apparent in this section. Even though the maximum profit is at the same level, the CPI allocation will result in insufficient investment, and thus will not realize the maximal profit. Therefore, optimal allocation must be applied to the investment in environmental management to enable efficient environmental investment.

4. Determining the Optimal Investment Level of Environmental Management

In this section, firstly, we deduce and explain the uncertain sales response function; secondly, Von Neumann-Morgenstern's utility theory (Menon and Menon, 1997) is adopted to determine the principal's objective, which is assumed to maximize the expected utility; the principal's investment level of environmental management is then determined. Lastly, a value simulation is performed and sensitivity analysis of several parameters is conducted to understand the correlation between the parameters and the investment level of environmental management or profit.

4.1 Uncertain Response Function as Submarket's Characteristics

4.1.1 Sales Response Function

We infer the sales response function from the demand function. We assume that the demand response functions of the two submarkets are:

$$P_i = a - b_i q_i + \epsilon_i, \ i = 1, 2 \tag{4-1}$$

This is a negative demand function, where ϵ_i is the normal distribution error item, which implies that the market has an uncertain situation. This uncertain situation is represented by this item. The average of ϵ_i is 0 and the variance is σ_i. In general, when investing in environmental management, companies will increase corporate cost. Thus, we modify Formula (4-1) as below:

$$P_i = a - b_i q_i + \theta X_i + \epsilon_i, \ i = 1, 2 \tag{4-2}$$

Where θ is the degree that consumers acknowledge the investment in environmental management. Assume $\theta > 0$, X_i is the investment in environmental management, hence, θX_i

represents the degree that the investment in environmental management can be reflected in the product price. To compute Submarket i's sales amount (dollar amount/period), Formula (4-2) should multiply by sales quantity. Thus,

$$s_i = R_i^* q_i = aq_i - b_i q_i^2 + \theta X_i q_i + \epsilon_i \text{ for } i = 1, 2. \quad (4\text{-}3)$$

Assume that the submarket information is known to the agent, and $\epsilon_1 + \epsilon_2$ shows normal distribution. The aggregate sales $S = s_1 + s_2$ and the aggregate profit $\pi = mS - C$ show the same normal distribution. The aggregate cost (C) associated with aggregate profit includes fixed investment level of environmental management (R), handling cost of environmental management and production cost. The so-called handling cost for environmental management is

$$C_{EM} = \sum_{i=1}^{2} (f_i + \gamma_i X_i^2), \ i = 1, 2 \quad (4\text{-}4)$$

Where f_i represents the fixed handling cost for environmental management, and γ_i is the environmental management investment efficiency. A smaller value of γ_i indicates higher efficiency in resource utilization. The production cost is

$$C_q = \sum_{i=1}^{2} (h_i + \rho_i q_i^2), \ i = 1, 2 \quad (4\text{-}5)$$

Where h_i represents the fixed cost of production, and ρ_i is the production efficiency factor. Same as γ_i, a smaller value of ρ_i indicates higher efficiency in resource utilization. Due to the uncertainty of sales response function, the profit should be expected profit, that is,

$$\pi = m \sum_{i-1}^{2} (aq_i - b_i q_i^2 + \theta x_i q_i + \epsilon_i) - R - C_{EM} - C \quad (4\text{-}6)$$

$$E(\pi) = m \sum_{i-1}^{2} (aq_i - b_i q_i^2 + \theta x_i q_i) - R - C_{EM} - C_q \quad (4\text{-}7)$$

Subject to

$$X_1 + X_2 \leq R, \ R \geq 0, \ i = 1, 2.$$

Assume that resources are fully utilized; hence, R should be exhausted. Moreover, if m = 1, and these two submarkets are independent of each other. The variance of the aggregate sales and profit is then

$$V = q_1^2 \sigma_1^2 + q_2^2 \sigma_2^2. \quad (4\text{-}8)$$

4.1.2 The Principal's Objective

In order to study the principal's environmental investment decisions when facing market uncertainty, we adopt Von Neumann-Morgenstern's utility theory (Menon and Menon, 1997), and assume that the principal objective is to maximize the expected utility. The utility function is,

$$U(\pi) = 1 - \exp(-A_I \pi) \tag{4-9}$$

In a fixed and absolutely risk-averse utility function, A_I is the coefficient of the principal's risk aversion. In the known utility function with uncertain profit of normal distribution, the R selected by the principal will maximize the expected utility, that is, maximize certainty equivalent (*CE*). Here, certainty equivalent is

$$CE = E(\pi) - (A_I/2)V \tag{4-10}$$

When $A_I > 0$, it indicates that the principal is risk averse, and a greater value of A_I indicates more averse risk to the principal. When $A_I = 0$, it indicates that the principal is risk neutral, that is, the principal will select R, which maximizes the expected utility and profit. In this case, $CE = E(\pi)$. Consequently, the agent's resources are allocated as follows:

$$\max CE = E(\pi) - (A_a/2)V \tag{4-11}$$

Subject to

$$X_1 + X_2 \leq R, \quad Q \geq 0, \quad i = 1, 2.$$

Again, assume that resources will be fully utilized; hence, R should be exhausted, where A_a is the coefficient of the agent's risk aversion. When $A_a > 0$, it indicates that the agent is risk averse, and a greater value of A_a indicates more averse risk to the agent. When $A_a = 0$, it indicates that the agent is risk neutral. The solution to Formula (4-11) is,

$$X_1^* = [a(\beta - \alpha)\theta + (2\gamma_2 \alpha\beta - \theta^2\alpha)R] / [2(\gamma_1 + \gamma_2)\alpha\beta - (\alpha + \beta)\theta^2] \tag{4-12}$$

$$X_2^* = [a(\alpha - \beta)\theta + (2\gamma_1 \alpha\beta - \theta^2\beta)R] / [2(\gamma_1 + \gamma_2)\alpha\beta - (\alpha + \beta)\theta^2] \tag{4-13}$$

$$q_1^* = \{a[2(\gamma_1 + \gamma_2)\beta - 2\theta^2] + \theta(2\gamma_2\beta - \theta^2)R\} / [2(\gamma_1 + \gamma_2)\alpha\beta - (\alpha + \beta)\theta^2] \tag{4-14}$$

$$q_2^* = \{a[2(\gamma_1 + \gamma_2)\alpha - 2\theta^2] + \partial(2\gamma_1\alpha - \partial^2)R\} / [2(\gamma_1 + \gamma_2)\alpha\beta - (\alpha + \beta)\theta^2] \tag{4-15}$$

Where $\alpha = 2b_1 + 2\rho_1 + A_a\sigma_1^2$; $\beta = 2b_2 + 2\rho_2 + A_a\sigma_2^2$. For the convenience of computation, we let

$$X_1^* = C + W_1 R \tag{4-16}$$

$$X_2^* = -C + W_2 R \tag{4-17}$$

$$q_1^* = D_1 + F_1 R \tag{4-18}$$

$$q_2^* = D_2 + F_2 R \tag{4-19}$$

Apparently, by this allocation method, from the principal's standpoint, the optimal allocation occurs only when $A_I = A_a$, that is, the agent's allocation behavior is equivalent to the principal's allocation behavior.

4.1.3 The Principal's Decision on the Investment Level of Environmental Management

Now, take the cause compatibility constraint in Formula (4-16) to (4-19) to the principal's aggregate sales response function, (4-20) is derived as below:

$$\begin{aligned} S = &(aD_1 - b_1D_1 + \theta CD_1 + aD_2 - b_2D_2 + \theta CD_2) \\ &+ (aF_1 - 2b_1D_1F_1 + \theta CF_1 + \theta W_1D_1 + aF_2 - 2b_2D_2F_2 - \theta CF_2 + \theta W_2D_2)R \\ &- (b_1F_1^2 - \theta W_1F_1 + b_2F_2^2 - \theta W_2F_2)R^2 + \epsilon_1(D_1 + F_1R) + \epsilon_2(D_2 + F_2R) \end{aligned} \tag{4-20}$$

Where C, W_1, W_2, F_1, F_2, D_1 and D_2 can be obtained from Formula (4-12) to (4-19). For the convenience of computation, we let

$$S = T_0 + T_1R + T_2R^2 + E \tag{4-21}$$

Where $T_0 = aD_1 - b_1D_1 + \theta CD_1 + aD_2 - b_2D_2 + \theta CD_2$;

$T_1 = aF_1 - 2b_1D_1F_1 + \theta CF_1 + \theta W_1D_1 + aF_2 - 2b_2D_2F_2 - \theta CF_2 + \theta W_2D_2$;

$T_2 = b_1F_1^2 - \theta W_1F_1 + b_2F_2^2 - \theta W_2F$; $E = \epsilon_1(D_1 + F_1R) + \epsilon_2(D_2 + F_2R)$

The average of the aggregate error item E is 0 and the variance is:

$$V(E) = (\sigma_1^2 D_1^2 + \sigma_2^2 D_2^2) + 2(\sigma_1^2 D_1 F_1 + \sigma_2^2 D_2 F_2)R + (\sigma_1^2 F_1^2 + \sigma_2^2 F_2^2) R^2 \tag{4-22}$$

By the same token, for the convenience of computation, we let

$$V(E) = V_1 + 2V_2R + V_3R^2 \tag{4-23}$$

Where $V_1 = \sigma_1^2 D_1^2 + \sigma_2^2 D_2^2$; $V_2 = \sigma_1^2 D_1 F_1 + \sigma_2^2 D_2 F_2$; $V_3 = \sigma_1^2 F_1^2 + \sigma_2^2 F_2^2$

The principal's certainty equivalent is simply computed as:

$$CE = T_0 + T_1R - T_2R^2 - R - C_{EM} - C_q - (A_I/2)(V_1 + 2V_2R + V_3R^2) \tag{4-24}$$

T_0, T_1 and T_2 can be obtained from Formula (4-20) to (4-21), and V_1, V_2 and V_3 can be obtained from Formula (4-22) to (4-23). When the principal's optimal investment level equals maximal certainty equivalent, that is,

$$RA=(T_1+G-1-A_I V_2)/(2T_2+K+A_I V_3) \tag{4-25}$$

Where $G=-2\gamma_1 CW_1+2\gamma_2 CW_2-2\rho_1 D_1 F_{1-2}\rho_2 D_2 F_2$; $K=2\gamma_1 W_1^2+2\gamma_2 W_2^2+2\rho_1 D_1 F_2^2+2\rho_2 D_2 F_2^2$

The RA is the environmental investment level of the risk-averse principal. If we assume, in Formula (4-25), $A_I=0$, then we can derive the environmental investment level of the risk-averse principal $R=RN$. Therefore, a value simulation is conducted in this paper for further analysis.

4.2 Value Simulation

Both positive environmental investment level and positive expected profit make a more meaningful case, which implies that the agent's individual rational constraint is satisfied. Consequently, we assumed that the coefficients of sales response function and error item are: $a=30$; $b_1=1$; $b_2=5$; $\gamma_1=0.8$; $\gamma_2=0.7$; $\rho_1=0.9$; $\rho_2=0.7$; $f_1=f_2=0.1$; $h_1=h_2=0.1$; $\theta=0.4$; $\sigma_1=0.5$; $\sigma_2=0.6$. For the convenience of computation, when both the principal and the agent are risk averse, assume $A_I=A_a=3$. With the above presumed parameters, the results in Table 4 can be derived.

Table 4. Risk-Averse vs. Risk-Neutral Allocation Results

	Risk-Averse Agent $X_1^*=0.5677+0.4699R$ $X_2^*=0.5677+0.5301R$ $q_1^*=6.6433+0.0413R$ $q_2^*=2.3857+0.0170R$		**Risk-Neutral Agent** $X_1^*=0.7151+0.4708R$ $X_2^*=-0.7051+0.5292R$ $q_1^*=7.97+0.0496R$ $q_2^*=2.6065+0.0186R$	
	Risk-Neutral Principal	Risk-Averse Principal	Risk-Neutral Principal	Risk-Averse Principal
Optimal Investment	$RN_a=1.3610$	$RA_a=1.0186$	$RN_n=1.4231$	$RA_n=0.9451$
Optimal Expected Profit from Investment	118.0873	153.6517	95.5050	165.5183
Aggregate Profit Variance of Optimal Investment	13.3097	13.2523	18.6582	18.5463

Based on the above description, we can see that when the principal deals with the agent of the same risk type, the risk-neutral principal will investment more than the risk-averse agent. Meanwhile, we can see a special phenomenon, that is, when the principal deals with agents of different risk types, when the principal and the agent shares the same attitude to risk tends to produce a more aggregate investment decision than when their risk aversion differs.

Table 5. Sensitivity Analysis of Parameters

Parameter	Attitude to Risk	Range	Correlation to Environmental Investment Level	Correlation to Expected Profit
The Degree that Consumers Acknowledge Environmental Investment (θ)	1	0.196～0.464 (Sufficient Minimum)	+	-
		3.35～3.368 (Sufficient Maximum)	+	-
	2	0.21～0.508	+	-
	3	0.23～0.5575	+	-
	4	0.22～0.579 (Sufficient Minimum)	+	-
		3.548～3.57 (Sufficient Maximum)	+	-
Submarket 1's Environmental Investment Efficiency Factor (γ_1)	1	> 0.61	-	+
	2	> 0.51	-	+
	3	> 0.47	-	+
	4	> 0.46	-	+
Submarket 2's Environmental Investment Efficiency Factor (γ_2)	1	> 0.07	-	+
	2	> 0.04	-	+
	3	> 0.04	+	-
	4	> 0.05	+	-
Submarket 1's Production Efficiency Factor (ρ_1)	1	0～5.3	-	< 0.31: - 0.31~2.71: + > 2.71: -
Submarket 1's Production Efficiency Factor (ρ_1)	2	0～5.3	-	< 0.38: - 0.38~1.86: + > 1.86: -
Submarket 1's Production Efficiency Factor (ρ_1)	3	0～4.92	-	< 0.72: - 0.72~1.48: + > 1.48: -
	4	0～4.37	-	< 0.68: - 0.68~1.17: + > 1.17: -
Submarket 2's Production Efficiency Factor (ρ_2)	1	All Positive	-	+
	2	All Positive	-	+
	3	All Positive	-	< 10.9: + > 10.9: -
	4	All Positive	-	< 8.9: + > 8.9: -

Note: 1. The principal and the agent are risk-neutral;
2. The principal is risk neutral whereas the agent is risk-averse;
3. The principal is risk averse whereas the agent is risk-neutral;
4. The principal and the agent are risk averse;
+: The parameter is positively correlated to the environmental investment level/the expected profit.
-: The parameter is negatively correlated to the environmental investment level/the expected profit.
"Range" refers to the range of the parameter when both the investment level and expected profit are greater than zero.

4.3 Sensitivity Analysis of Related Parameters

In this section, the sensitivity analysis is done on the relationships that such five parameters as the degree that consumers acknowledge environmental investment (θ), environmental investment efficiency factors (γ_1 and γ_2), and production efficiency factors (ρ_1 and ρ_2), have with the investment level of environmental managementa nd the expected profit. Since the positive investment level of environmental managementa nd expected profit make more sense, in parameter analysis, we only consider the case when both the environmetnal management investment level and expected profit are greater than zero. Based on the above sensitivity analysis of parameters, we summarize the results in Table 5 as below:

5. Conclusions and Recommendations

5.1 Conclusions and Recommendations

This paper provided an integrated decision-making method relative to the decision-making of investment level. In particular, we emphasized the value of the detailed and optimal allocation decision. The analyses and illustrations in this paper include some special assumptions, for instance, the dynamic impact is not taken into account; sales response function and parameters are analyzed in explanation. According to the theoretical inference and analysis, we can learn:

- Different approaches to investment allocation have different impacts on the aggregate response (sales and profit). We found that the aggregate response to the optimal allocation method was better than that to the allocation by ratio. The allocation by ratio will usually cause excess investment or insufficient investment.
- As the change in the optimal aggregate response increases with the investment level, we found that the submarket investment does not increase proportionately. This phenomenon is particularly noticeable when the submarket is characterized by beyond-saturation sales response.
- From the value simulation in this paper, we have found that the risk-neutral principal invests more than the risk-averse principal. If the principal faces agents of different risk types, when the principal and the agent share the same attitude to risk tend to generate a more aggregate investment decision than when their risk aversion differs.
- Aggregate sales and profit are more sensitive to the change of investment allocation method than the change of investment level. Therefore, companies can usually achieve more evident benefits when adopting the optimal allocation method than adjust the investment level.
- With regard to the parameter sensitivity analysis in Section 4, the findings are:

(1) The degree that consumers acknowledge the environmental investment (θ) is pos-

itively related to the investment level of environmental management but negatively related to the expected profit.

(2) The environmental investment efficiency factors (γ_1 and γ_2) are related to the investment level of environmental management and the expected profit.

(3) In the sensitivity analysis of the relationship between production efficiency factors (ρ_1 and ρ_2), we found that regardless whether the principal or agent is risk neutral or risk averse, the production efficiency factors are negatively related to the environmental management investment level, which means that a smaller value of the production efficiency factor implies higher efficiency. Hence, when the production is more efficient, enterprises tend to investment more in environmental investment.

As a result, in the corporate investment allocation decision making process, an integrated approach, instead of a top-down approach, should be used to determine the investment level and allocation method. In making allocation decisions, it's better to use submarket information rather than aggregate market information. Therefore, in determining the investment level, the executive management should consider the willingness of the agent. Meanwhile, in allocating the investment, the agent should find the optimal allocation method based on submarket information.

5.2 Future Research Direction

This paper focuses on the theoretical inference only at the current stage. The future researches may take the viewpoints from this paper and design a questionnaire for survey and analysis to understand if the viewpoints in this paper match the reality. The time factor was not considered in this paper, under which circumstance, the environmental investment has a negative relationship with the expected profit; hence, the subsequent researches may take the time factor into account in the model. In addition, since only three types of sales response functions were studied in this research while there are various market types in the real world, further researches may be conducted regarding the other market types. Of course, government policies can also be included in the model to analyze the role that government policies play in corporate environmental investment decision-making process.

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