

An Interaction between Government and Manufacturer in Implementation of Cleaner Production: A Multi-Stage Game Theoretical Analysis

Zhao, R.* , Peng, D. and Li, Y.

Faculty of Geosciences and Environmental Engineering, Southwest Jiaotong University,
Chengdu 611756, China

Received 8 Oct. 2014;

Revised 7 Jan. 2015;

Accepted 15 Jan. 2015

ABSTRACT: This paper shows how game theory can be applied to modeling the interaction between government and manufacturer in implementation of cleaner production. A generic game model based upon ‘Two-person Non-cooperative’ static game is created to allow various strategic actions being tested by stages, and aid decision making by selecting optimal strategy for both manufacturer and policy maker to reduce lifecycle based environmental impact while maximizing the economic benefits. The game theoretical result suggests a ‘win-win’ strategic situation as the best interaction, which indicates that manufacturer implements the clean technology voluntarily and government no longer needs to intervene intensely in manufacturer’s environmental unfriendly behavior. In addition, a case example is given to help a tombarthite manufacturer select the feasibly optional clean technology to improve the existing process of production, which provides a useful insight into the application of game theory. Limitations of the game theoretical analysis are discussed to lay out a foundation for further study.

Key words: Game theory, Cleaner Production, Interaction, Strategic action

INTRODUCTION

From the perspective of ‘Hierarchy of Waste Management’, cleaner production is demonstrated as an effective way to prevent environmental contamination and promote sustainable development, which is both environmentally and economically beneficial to business, environment and society (Tseng *et al.*, 2009; Zhao *et al.*, 2012). It aims at the development of new technologies or upgrading the existing manufacturing processes to reduce the amount of waste, the consumption of raw materials, as well as to mitigate the adverse impact on environment and human health (Tchobanoglous and Kreith, 2002; Williams, 2005; Zhao *et al.*, 2013).

Both Government and Manufacturers can be regarded as the significant ‘actors’ involved in the programme of cleaner production (Zhao *et al.*, 2013). Government is leading society on the path to sustainability, including contributions to environmental protection, economic development and public satisfaction (Kemp *et al.*, 2005; van Zeijl-Rozema *et al.*, 2008). With regard to the cleaner production, government aims at encouraging demand for

environmentally friendly products and services, helping business reduce lifecycle environmental impact, driving innovation, research and design for products’ sustainability (Skea and Nishioka, 2008; Tseng *et al.*, 2013). These actions mainly are enforced by well-designed environmental policies, investment of technical innovation, allowance for equipment upgrading *etc* (Elkington, 1997; Dong *et al.*, 2010). However, governmental actions may confront with uncertainty, *e.g.* the inflexible legislation or regulation will only intensify in number and scope if manufacturer does not respond, although it is originally intended to drive enterprises towards sustainability (Kane, 2010). Given the complexity, there are also “incentives or sanctions”: how should government establish the reasonable incentive and punitive mechanism? For example, how many revenues from landfill tax can be returned back to support business in improving resource efficiency (OECD, 2004). For manufacturer, there are three hierarchies to run a business from bottom to top, *i.e.*, basic market demand, a sustainable source of raw materials and energy for production, achieving ‘green’ societal value for environmental protection gradually (Kane, 2010; Zhao *et al.*, 2013).

*Corresponding author E-mail: ruizhaoswjtu@hotmail.com

Manufacturer is primarily driven by profitable motivation as the bottom line for business, while not taking the full lifecycle of products into account, and even does not regard waste prevention as a key management area (Henriques, 2004; Deutz *et al.*, 2010). With the implementation of cleaner production, it is inevitably that manufacturer should pay more attention to corporate social responsibilities (CSR). For instance, some blue chip organizations focus not only on the economic value, but also the environmental and social impact, by which corporate governance, risk management and control, business accounting and reporting can be also enhanced (Elkington, 1997; Monaghan, 2004). However, it is uncertain that whether manufacturer is willing to undertake more corporate social responsibilities except for compliance with governmental policy. This question becomes should manufacturers preempt implementing action and seek to gain a competitive advantage or key selling point. Thus, a 'cleaner production' game is arising from a large area of common and possible conflict of interests between government and manufacturer.

In this paper, how game theory can be applied to modeling the interaction between Government and Manufacturer is presented. We first provide a review of the existing literature on game theory application to cleaner production, and then use a 'rich picture' to illustrate a possible game situation in order to understand the principal drivers, actors *etc.* A "Two-person Non-cooperative" generic game model is created to test strategic actions selected by the government and manufacturer, and search for the optimal strategy to promote cleaner production. In addition, we give a case example to help a tombarthite manufacturer select the feasibly optional clean technology to improve the existing process of production, thus to demonstrate the application of game theory. Conclusions regarding game theory as a useful tool for the stakeholders involved in the cleaner production are provided with suggestions to improve the game model.

Game theory is regarded as a mathematical and logical approach of strategic decision making, helping decision makers improve the results of their strategic choice by predicting the possible outcomes in the course of competition and cooperation (Reniers and Pavlova, 2013). It has been widely applied to various research fields, such as economics, marketing, production management *etc.* (Sun *et al.*, 2013). In the scope of industrial manufacturing management, game theory allows identification of optimal strategies in order to help better decision-making (Wang, 2007).

Qiu *et al.* (2005) discussed the possibility of using non-cooperative game theory to help resource

controller make appropriate reconfiguration decisions. The game theoretical approach showed a good performance of optimizing resource sharing based upon local information and autonomous manner. Wang (2007) incorporated data mining algorithms into game theory to aid better selection of manufacturing system. Real-world manufacturing datasets were examined by the hybrid approach, *i.e.* using data mining techniques to deal with the game theoretical data to provide an insight into complex engineering systems analysis. Game theory was used for information standardization in manufacturing enterprise (Jiang *et al.*, 2008). A scheme collection of information standardization was generated for execution by the established non-cooperation and cooperation game model. Zhou *et al.* (2009) proposed a game theoretical based model, *i.e.* N-person non-cooperative game model with complete information, to handle with job scheduling issue in networked manufacturing environment. Similarly, Arasteh *et al.* (2014) introduced cooperative game theory application to address scheduling optimization. Lu *et al.* (2012) proposed game theoretical approach to concurrent tolerance design by taking manufacturing and assembly process into account, in order to reduce manufacturing cost and improve assemblability of products. Similar to Zhou *et al.* (2009), they also used the genetic algorithm to search subset of Nash equilibria as the optimal tolerance design.

In addition to the traditional manufacture, green or sustainability has been embodied into manufacturing process, to eliminate waste, hazardous materials to human health and environment, save energy *etc.* (Santochi and Failli, 2013). In this context, the application of game theory has been discussed by a number of works in the field of energy management, renewable energy production (Nasiri and Zaccour, 2009; Aplak and Sogut, 2013; Luo and Miller, 2013), and better policy making on implementation of clean technology (Dong *et al.*, 2010; Zhao *et al.*, 2013). For energy management, Nasiri and Zaccour (2009) proposed a game model to discuss utilization of biomass for power generation, with three players being investigated, *i.e.* distributor, facility developer and participating farmer. The study paid a close attention to the impact of incentives on their actions. Additionally, Luo and Miller (2013) focused on biomass production by using game theory based on a nonlinear optimization model to help decision-making on incentives for driving the industry to obtain cellulosic ethanol. Aplak and Sogut (2013) used Multi-Criteria Decision Making method to derive a game payoff matrix, with two entities as 'Industry' and 'Environment' being involved. The study indicated renewable energy in industry should be a way to promote environmental protection. With regard to the

policy making on clean technology, Dong *et al* (2010) proposed a game theoretical framework to investigate the possible responses for electroplating firm. On this basis, Zhao *et al* (2013) used a ‘Gambit’ software tool to simulate a game between government and manufacturers in implementation of cleaner production.

Most of the previously mentioned game theoretical analyses are based upon mathematical optimization, to help manufacturers enhance their productivity, which are quite useful in informing our approach. However, few of them have addressed the issues of interaction between government and manufacturer raised in the cleaner production. Especially, the results derived from the game models with complex equations containing vast parameters or data, may not be easily understood by the stakeholders involved in a game, thus to limit its wider application (Wang, 2007; Zhao *et al.*, 2013). This study aims at providing a simple game scenario to model the possible actions of local government and manufacturer in implementation of cleaner production. The game parameters are deemed as generic to help the stakeholders better understand the interaction. A case example is given to verify the game theoretical analysis.

MATERIALS & METHODS

In order to evaluate the ‘game situation’, a ‘rich picture’ is developed (Fig. 1) by means of soft systems methodology (SSM), to understand the principal actors, and influences upon the ultimate environmental impact. SSM was proposed by Prof. Peter Checkland from Lancaster University in the early 1980’s, now has been developed as an insightful tool to evaluate complex environments, that enables expression of problem situations by dealing with questions about ‘why’ and ‘what’ we should do, as well as determining ‘how’ to do (Checkland and Scholes, 1990; Checkland, 1999; Wilson, 2001). Drawing the ‘rich picture’ is the first stage of the SSM, to present the structure, processes, and issues of a specific system, which provides a holistic framework of actual activities, in order to hold a scrutiny of the problem situation (Presley *et al.*, 2000; Jackson, 2003). The game results from the product development responding to the public’s demand and their resulting consumption. It is important to identify that commercial products are sometimes manufactured using materials that are

potentially ‘hazardous’, from which public health may be affected because of the inherent risk, and in some cases the health effects can be substantial. Accordingly, public is set at a finite risk from everyday consumer products. For instance, formaldehyde is a common material used in furnishings. However, the public are prepared to accept this risk on account of the useful value of the products (McGuire *et al.*, 2010). To provide better and safer alternatives to consumer products, it is the duty of government to regulate the manufacturing process. In addition, manufacturer is willing to seek more commercial opportunities by sales of environmentally sound products and services through the improvement of products’ environmental performance (Fairchild, 2008). In the following sections, government and manufacturer, with their conflict of interests are introduced in terms of a generic game framework.

The game framework is built with two involved players: government (G) and manufacturer (M). Each of them has two available strategies. For the government, the strategies are: {I, NI} which indicate whether government should inspect (I) not inspect (NI) the manufacturer by choosing clean technology to upgrade manufacturing process. Accordingly, two strategies for manufacturer are {IMP, NIMP}. ‘IMP’ indicates that manufacturer determines to improve product quality and reduce environmental impact in implementation of cleaner production, whilst ‘NIMP’ denotes not to implement. Table 1 shows the payoffs matrix for the two players with different strategic actions. In Table 1, ‘R’ denotes the possible revenue that government is expected from the implementation of clean technology, ‘S’ the governmental subsidy, *e.g.*, equipment subsidy and tax break, to help the manufacturer upgrade the existing production by selection of clean technology, ‘C’ the cost of the manufacturer in compliance with the standard of clean technology, ‘E’ the expected economic benefit for the manufacturer while using clean technology, ‘P’ the economic penalties for the manufacturer’s environmentally unfriendly behavior, ‘L’ the possible loss (L) in terms of the lifecycle based environmental impact of the manufacturer, *e.g.* waste emission, waste water discharge, carbon emissions *etc.*

Generally speaking, a game is categorized as cooperative and non-cooperative (Thomas, 2003). Their

Table 1. Payoff matrix for Government (G) and Manufacturers (M)

	M		
G		IMP	NIMP
I		$R-S, S-C+E$	$P-L, -P$
NI		$R, -C+E$	$-L, 0$

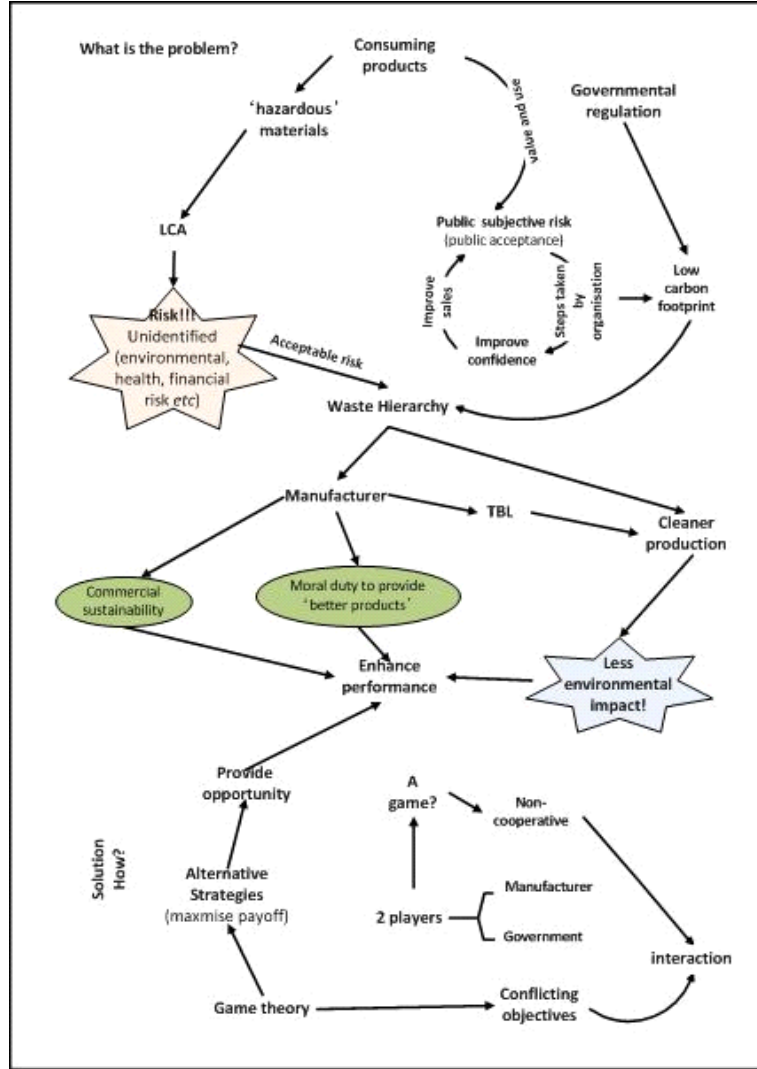


Fig. 1. A 'Rich Picture' of a possible game

differences can be distinguished by whether agreements or commitments in a game are enforceable (Geckil and Anderson, 2010). In this game, both government and manufacturer are considered as rational who are intended to maximize their self-interests while acting simultaneously, *i.e.*, to maximize their payoffs. Thus, the game can be seen as static and non-cooperative (Geckil and Anderson, 2010). The solution of a game is determined by "Nash Equilibrium", which makes the unique predication with a best response from the possible strategic actions that each player may choose (Fundenberg and Tirole, 1991; Gibbons, 1992).

Game Stage 1:

If the payoff that the manufacturer chooses to implement cleaner production (IMP) is lower than Non-implementation (NIMP), the following equalities apply:

$$E - C + S < -P \quad (1)$$

$$E - C < 0 \quad (2)$$

The above two equations can be transformed as $E + S < C - P$, reflected that the economic return (E) and governmental subsidy (S) cannot cover the cost (C). Combined with $P-L > -L$, the dominant strategy is that the manufacturer is not willing to implement cleaner production (NIMP), whilst government should inspect the manufacturing process (I). Here, a dominant strategy can be expressed as a unique pair of equilibrium (NIMP-I) for this game, shown in Figure 2. In addition, this scenario indicates that manufacturer may prefer paying the penalties rather than upgrading the existing production due regard to the cost consideration and insufficient surveillance from government, *e.g.* a lower economic sanction.

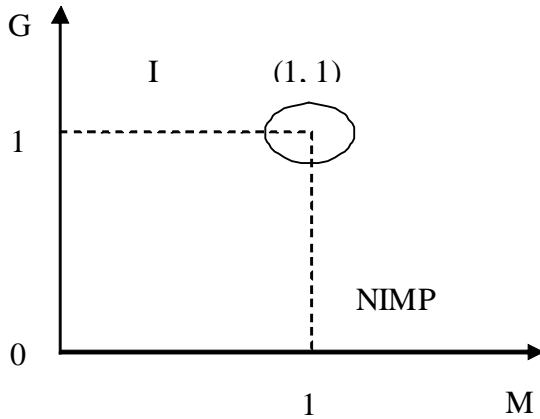


Fig.2. Equilibrium pair of game stage 1

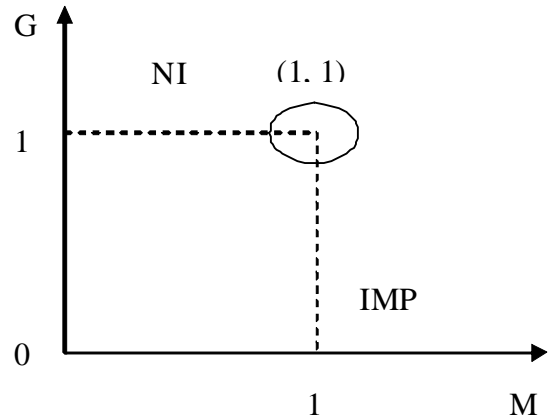


Fig.3. Equilibrium pair of game stage 3

Game Stage 2:

Once the government sets a heavier penalty for the manufacturer's non-implementation behavior, the manufacturer may re-exam the payoff. As long as the Eqs.3 and 4 are both satisfied, the first game is evolved as a mixed-strategy game scenario, in which a probabilistic distribution is placed by the strategies selection.

$$E - C + S > -P \tag{3}$$

$$E - C < 0 \tag{4}$$

In this case, let U_{IMP} ($0 \leq U_{IMP} \leq 1$) denote the probability that the manufacturer takes the action of 'Implementation' (IMP), $U_{NIMP} = 1 - U_{IMP}$ the probability of choosing 'Non-implementation' (NIMP). Similarly, let V_I ($0 \leq V_I \leq 1$) denote the probability that the government selects 'Inspection' (I), $V_{NI} = 1 - V_I$ for 'Non-Inspection' (NI). Thus, the expected payoff for the manufacturer and government are expressed as $E_M(u,v)$, $E_G(u,v)$, respectively.

$$E_M(u,v) = U_{IMP} \times [V_I \times (E - C + S) + (1 - V_I) \times (-C + E)] + (1 - U_{IMP}) \times (-V_I \times P) \tag{5}$$

$$E_G(u,v) = V_I \times [U_{IMP} \times (R - S) + (1 - U_{IMP}) \times (P - L)] + (1 - V_I) \times [U_{IMP} \times R - (1 - U_{IMP}) \times L] \tag{6}$$

Let, $\frac{\partial E_M(u,v)}{\partial U_{IMP}} = 0$ the Eq.5 becomes:

$$V_I = \frac{C-E}{S+P} \tag{7}$$

$$V_{NI} = 1 - \frac{C-E}{S+P} \tag{8}$$

Similarly, let $\frac{\partial E_G(u,v)}{\partial V_I} = 0$, the Eq.6 is transformed as follows:

$$U_{IMP} = \frac{P}{S+P} \tag{9}$$

$$U_{NIMP} = 1 - \frac{P}{S+P} \tag{10}$$

From the Eqs.3, 4 and 7, $0 < V_I = \frac{C-E}{S+P} < 1$ can be obtained. When $S+P$ is fixed, V_I is evolved as an increasing function of $C-E$, indicated that the manufacturer has less economic return on the implementation of cleaner production. However, government has to enhance the efficiency of surveillance to enforce the manufacturer to undertake more environmental responsibilities. When $C-E$ is fixed, V_I is approached to 0 with $S+P$ growing, which indicates that government may opt to reduce the probability of inspection gradually. This is because the manufacturer may be either affected by governmental incentives or heavy fines, thus to tend towards cleaner production. From the Eq.9, it is clear that U_{IMP} will increase gradually from 0 to 1, as P rises. In this case, the manufacturer is more willing to apply clean technology to avoid the heavy economic penalties for the environmentally unfriendly actions.

Game Stage 3:

If the payoff that manufacturer chooses implementation (IMP) is higher than Non-implementation (NIMP), the following equalities satisfy:

$$E - C + S > -P \tag{11}$$

$$E - C > 0 \tag{12}$$

$E - C > 0$, *i.e.* $E > C$, denoted that the manufacturer's expected economic return can cover the cost for clean technology application. As $R > R - S$, the dominant strategy appears to be changed as the manufacturer attempts to comply with cleaner production voluntarily (IMP), whilst government no longer needs scrutiny for the manufacturing (NI), shown in Fig. 3.

RESULTS & DISCUSSION

Based on the above analysis, it is evident that the strategic actions of government and manufacturer are strongly determined by the following factors, *i.e.* the economic penalties (P), governmental subsidy (S), cost of implementation (C) and expected economic returns (E), shown in Fig.4. In addition, three game stages are generated by the variance of these game parameters, which are involved in the pure and mixed strategy game scenarios. Table 2 shows how these factors are measured. A limited company of tombarthite manufacturer in Sichuan Province, China, has been investigated to access the possible strategic behaviors in a numerical game framework. The tombarthite manufacturer has provided various products, such as praseodymium oxide, lanthana, lanthanum chloride *etc.*, which are complied with International Standardization Organization (ISO) 9001 and accredited by National Qualification Standard. There are two optional technologies to upgrade the existing manufacturing process, *i.e.*, opti-

mization of hydrochloric acid leaching and reconstruction of coiler of the evaporation and concentration tank. For the former technology, the annual consumption of the hydrochloric acid, ammonium hydroxide, ammonium bicarbonate and quick lime are expected to reduce 707.5 tonnes, 1387.8 tonnes, 960.6 tonnes, 1509.3 tonnes, respectively. In addition, 1277 tonnes of fluorine-containing waste water is estimated to be reduced annually, whilst electricity saving is 3625.8 kwh. For the latter one, 51000 cubic metres of water is reduced for consumption annually. Moreover, the numerical values regarding of the two options are shown in Table 3.

Analysis of Option 1. As the expected economic return (E) cannot cover the cost for clean technology (C), *i.e.* $E < C$, following two expressions can be derived by the determined numerical values in Table 3.

$$C - E = 187900 \tag{13}$$

$$S + P \in [168750, 690000] \tag{14}$$

Based on Eqs.13 and 14, $S + P$ can be divided into two mathematical intervals. For $S + P \in [168750, 187900)$, $C - E > S + P$ can be obtained, which has verified the first stage of the pure strategy scenario. Due to less economic return, the tombarthite manufacturer is reluctant to implement clean manufacturing (NIMP). However, the local government should reinforce the inspection (I) by giving specifications of incentive and punitive policies.

For $S + P \in [187900, 690000]$, $C - E < S + P$ can be obtained, which is corresponding to the second game

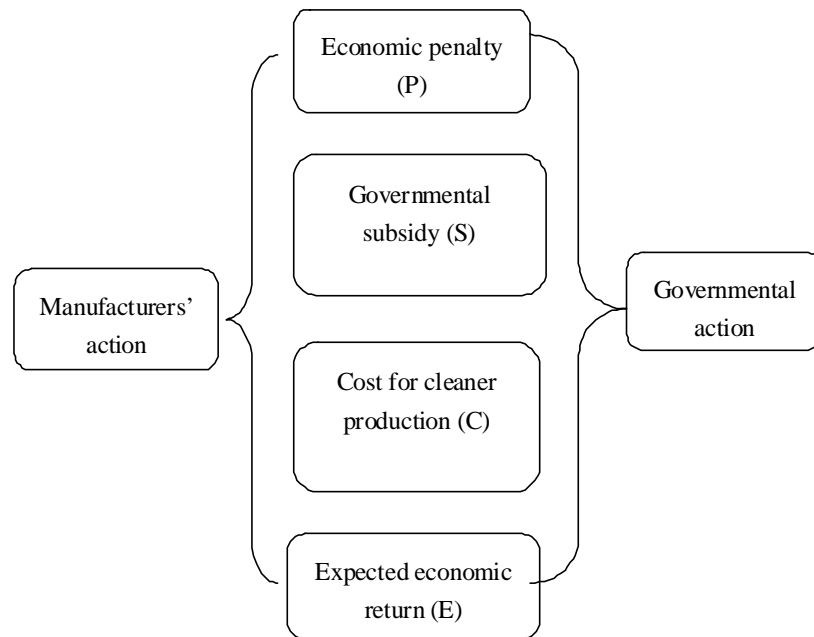


Fig.4. Key influencing factors in the game

Table 2. Measurement of the key influencing factors

Factors	Measurement
Economic Penalty (P)	The economic penalty is set between 50,000 and 500,000 (CNY). This data is derived from the “Cleaner Production law of Peoples’ Republic of China” (China NPC, 2012).
Governmental Subsidy (S)	Governmental subsidy (S) has been divided into equipment subsidy r and tax break k . $S = C * (r + k)$ Equipment subsidy accounts for 15% to 30% of the total investment for cleaner production, and tax break has a proportion of 10% (China NPC, 2007; Wang, 2010).
Cost for cleaner production (C)	The cost (C) is deemed as the initial outlay of investment for cleaner production, composed of cost for technological innovation C_{TI} , equipment upgrading C_{EU} , materials selection C_{MS} and labour training C_{LT} , which can be expressed as followed: $C = C_{TI} + C_{EU} + C_{MS} + C_{LT}$
Expected economic return (E)	Economic Return of cleaner production (E) is regarded as the present value of all future benefits which can be expressed as followed (Wills and Finney, 2004): $S = \sum_{t=1}^n \frac{O_{EA}}{(1+i)^t}$ where: O_{EA} denotes expected annual net cash flow from cleaner production i denotes the discount rate annually. Here, i equals to 0.06, derived from the latest policy set by Sichuan Provincial Government (Hou, 2011). O_{EA} can be measured as followed: $O_{EA} = N_A + \frac{C}{Y}$ where: N_A is annual net profit C is initial outlay of investment Y is depreciable period, assumed as 10 years (Hou, 2011).

stage. As $C - E$ is fixed, the probability of inspection (I) of the local government is decreased gradually from 1 to 0, as $S + P$ increases, especially the economic penalty increases, shown in Figure 5a. Oppositely, the probability of Non-Inspection (NI) of the local government increases rapidly with increased the governmental subsidy (S), shown in Figure 5b. Subsidies may be considered as a form of cost reduction, which may help the manufacturer act to be more environmentally friendly (Green, 2006). Thus, the tobarthite manufacturer’s implementation probability is increased with the economic penalty set by the local government, and vice versa, shown in Figure 5c and Fig. 5d.

Analysis of Option 2. It is apparent that the economic return (E) is considerably greater than the cost for cleaner production (C), i.e. $E \gg C$, which has verified the third game stage. Thus, action of ‘IMP’ is

the tobarthite manufacturer’s dominant strategy, by which more business and environmental opportunities are implied to be generated, e.g., improvement of product quality, reduction of energy consumption etc. However, neither governmental subsidy (S) nor economic sanction (P) plays a key role for the strategic selection, no matter how the parameter changes in this scenario. In this case, it is unnecessary for the local government to intervene manufacturing process strongly, indicated as ‘NI’, due to manufacturer’s voluntary implementation. This scenario suggests a best response of the interactions between the government and manufacturer, which can be deemed as a ‘win-win’ strategy for both parties. *Discussion.* While raising the economic penalties, the probability of implementation for manufacturer increases, but the intensity of governmental inspection decreases. Manufacturer is more willing to employ the clean technology voluntarily, thus to avoid the heavy

Table 3. Numerical values of two alternative options for the tombarthite manufacturer

Game Parameters China Yuan (CNY)	Option 1 reconstruction of coiler of the evaporation and concentration tank	Option 2 optimization of hydrochloric acid leaching
Economic Penalty (P)	50,000 to 500,000	50,000 to 500,000
Governmental Subsidy (S)	118,750 to 190,000	103,250 to 165,200
Cost for Clean Technology (C)	475,000	413,000
Expected Economic Return (E)	287,100	4,755,700

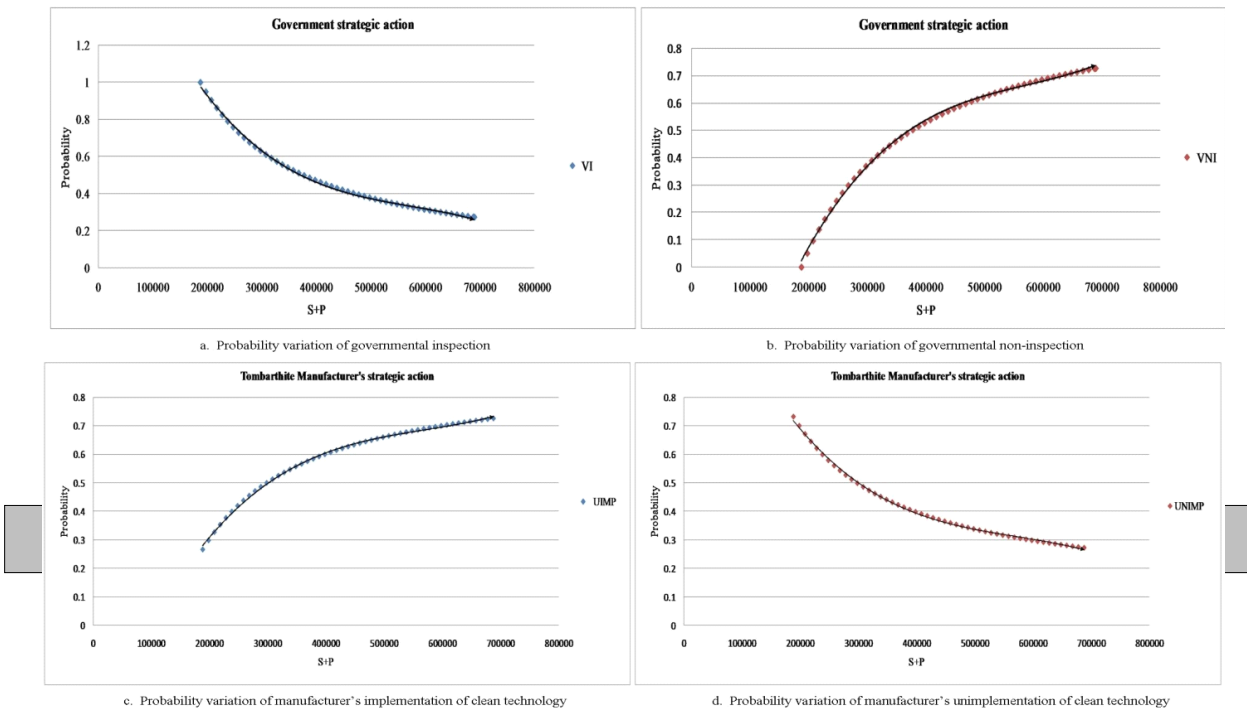


Fig.5. Strategic actions in the mixed-game scenario

economic penalties. For government, it is suggested reducing the inspecting intensity gradually due regard to the regulatory cost saving. The increase of governmental subsidy may lead the manufacturer to applying clean technology. These can be verified by analogy to Dong et al. (2010) of application game theory to the cleaner production in the Chinese electroplating industry, which indicates that both economic penalties and subsidies have an impact on the policy implementation. Compared with Option 1, it is suggested that the Option 2, *i.e.* ‘optimization of hydrochloric acid leaching’, should be more applicable to the tombarthite manufacturer, due to the larger economic return, energy saving, reduction of environmental pollution *etc.* Only if the governmental subsidy can be set as high enough, it is expected the manufacturer chooses reconstruction of coiler of the evaporation and concentration tank to improve the existing process.

CONCLUSIONS

The application of game theory provides a useful insight to better understand the interaction between government and manufacturer in the context of a cleaner production game. A ‘Two-person Non-cooperative’ static game framework between manufacturer and government is built to reflect the variation trend of strategic actions.

The game theoretical analysis aids strategic decision-making by selecting appropriate strategies for both organizations and policy makers to reduce environmental impact whilst maximizing the economic benefits. The game is strongly determined by economic penalties (P), governmental subsidy (S), cost (C) and the expected economic returns (E). In addition, a tombarthite manufacturer is investigated to verify all the stages in the game theoretical analysis. A ‘win-win’ strategy is suggested that the manufacturer may

implement cleaner production voluntarily (IMP) and the local government no longer needs to intervene strongly in inspection (NI).

As it is evident that consumers drive the open market, their preferences for 'environmentally friendly products' may be an important factor to result in 'green consumption', and even may influence decision-making from manufacturer and government, *e.g.* industrial upgrading, governmental policies *etc.* However, the interactions between government, enterprises and customers have yet been considered. Further study will focus on improvement of the proposed game model to represent the complexity between government, manufacturer and other stakeholders.

ACKNOWLEDGEMENTS

This work is sponsored by National Natural Science Foundation of China (No.41301639), The Fundamental Research Funds for the Central Universities (No. A0920502051408), The State-province Joint Engineering Laboratory of Spatial Information Technology for High-Speed Railway Safety (No. IRT13092).

REFERENCES

Aplak, H.S. and Sogut, M.Z. (2013). Game theory approach in decisional process of energy management for industrial sector. *Energ. Convers. Manage.*, **74**, 70-80.

Arasteh, A., Jalali-Naini, S.G. and Aliahmadi, A. (2014). Considering the game-theoretic approach and ultra combinative costs on scheduling. *Int. J. Adv. Mfg Technol.*, **70(5-8)**, 1473-1485.

Checkland, P. and Scholes, J. (1990). *Soft systems methodology in action.* (Chichester: John Wiley & Sons).

Checkland, P. (1999). *Systems thinking, systems practice: Includes a 30-year retrospective.* (Chichester: John Wiley & Sons).

China NPC (National People's Congress). (2007). *Corporate income tax law of Peoples' Republic of China.* Beijing: China Legal Publishing House. (In Chinese)

China NPC (National People's Congress). (2012). *Cleaner production promotion law of Peoples' Republic of China.* Beijing: China Legal Publishing House. (In Chinese)

Deutz, P., Neighbour, G. and McGuire, M. (2010). Integrating sustainable waste management into product design: sustainability as a functional requirement. *Sustain. Dev.*, **18**, 229-239.

Dong, X.Q., Li, C.L., Li, J., Wang, J. and Huang, W.T. (2010). A game-theoretic analysis of implementation of cleaner production policies in the Chinese electroplating industry. *Resour. Conserv. Recy.*, **54**, 1442-1448.

Elkington, J. (1997). *Cannibals with forks: The triple bottom line of 21 century business.* Oxford: Capstone.

Fairchild, R.J. (2008). The manufacturing sector's environmental motives: A game-theoretic analysis. *J. Bus. Ethics.*, **79(3)**, 333-344.

Fudenberg, D. and Tirole, J. (1991). *Game theory.* Cambridge: MIT Press. p.11.

Geckil, I.K. and Anderson, P.L. (2010). *Applied game theory and strategic behaviour.* London: Chapman&Hall.

Gibbons, R. (1992). *A primer in game theory.* London: Prentice Hall. pp. 8-14.

Green, A. (2006). You can't pay them enough: subsidies, environmental law and social norms. *Harv. Environ. Law. Rev.*, **30(2)**, 407-440.

Henriques, A. (2004). CSR, sustainability and the triple bottom line. (In A. Henriques & J. Richardson (Eds.), *The triple bottom line: does it all add up?* (pp. 29-30). London: Earthscan.)

Hou, A.Z. (2011). *A case study on cleaner production for rare earth industry: taking Leshan Shenghe rare earth company as an enterprise.* Master of thesis, Southwest Jiaotong University, Chengdu, China. (In Chinese with English Abstract)

Jackson, M.C. (2003). *System thinking: creative holism for managers.* Chichester: John Wiley & Sons.

Jiang, J.J., Wang, J.B., Li, S. and Zhang, J.X. (2008). Game theory strategy for information standardization work in manufacturing enterprise. (In T.X. Yan, C.Y. Jiang & B. Eynard, (Eds.), *Advanced design and manufacture to gain a competitive edge* (pp.503-512). London: Springer.)

Kane, G. (2010). *The three secrets of green business: unlocking competitive advantage in a low carbon economy.* London: Earthscan.

Kemp, R., Parto, S. and Gibson, R.B. (2005). Governance for sustainable development: Moving from theory to practice. *Int. J. Sustain. Dev.*, **8(1-2)**, 12-30.

Lu, C., Zhao, W.H. and Yu, S.J. (2012). Concurrent tolerance design for manufacture and assembly with a game theoretic approach. *Int. J. Adv. Mfg Technol.*, **62(1-4)**, 303-316.

Luo, Y. and Miller, S. (2013). A game theory analysis of market incentives for US switchgrass ethanol. *Ecol. Econ.*, **93**, 42-56.

McGuire, M.A., Neighbour, G.B. and Price, R. (2010). Should subjective risk be taken into account in the design process for graphite disposal? (In G.B. Neighbour (Eds.), *Securing the safe performance of graphite reactor cores* (pp. 229-242). Cambridge: Royal Society of Chemistry.)

Monaghan, P. (2004). Put up or shut up. (In A. Henriques & J. Richardson (Eds.), *The triple bottom line: does it all add up?* (pp. 142-154). London: Earthscan.)

Nasiri, F. and Zaccour, G. (2009). An exploratory game-theoretic analysis of biomass electricity generation supply chain. *Energy Policy*, **37**, 4514-4522.

OECD (Organization for Economic Cooperation and Development). (2004). *Addressing the economics of waste.* Paris: OECD Publications.

- Presley, A., Sarkis J. and Liles, D.H. (2000). A soft-systems methodology approach for product and process innovation. *IEEE-Tem.*, **47(3)**, 379-392.
- Qiu, R.G., McDonnell, P., Joshi, S. and Russell, D.W. (2005). A heuristic game theoretic approach to resource sharing in reconfigurable manufacturing. *Int. J. Adv. Mfg Technol.*, **25(1-2)**, 78-87.
- Reniers, G. and Pavlova, Y. (2013). Using game theory to improve safety within chemical industrial parks. London: Springer.
- Santochi, M. and Failli, F. (2013). Sustainable work for human centred manufacturing. (In H. Bartolo, (Eds.), Green design, materials and manufacturing processes (pp. 161-166). London : Taylor & Francis.)
- Skea, J. and Nishioka, S. (2008). Policies and practices for a low-carbon society. *Clim. Policy*, **8**, S5-S16.
- Sun, H.J., Wu, J.J., Wang, W. and Zhang, W.Y. (2013). Production game of multifirms with different decision-making patterns. *Proc. IMechE, Part B.*, **227(9)**, 1393-1402.
- Tchobanoglous, G., Kreith, F. (2002). Handbook of solid waste management. 2nd ed, New York: McGraw-Hill. pp.1-39.
- Thomas, L.C. (2003). Games, theory, and applications. Mineola: Dover Publications.
- Tseng, M.L., Lin, Y.H. and Chiu, A.S.F. (2009). Fuzzy AHP-based study of cleaner production implementation in Taiwan PWB manufacturer. *J. Clean Prod.*, **17(14)**, 1249-1256.
- Tseng, M.L., Chiu, A.S.F., Tan, R.R. and Siriban-Manalang, A.B. (2013). Sustainable consumption and production for Asia: sustainability through green design and practice. *J. Clean Prod.*, **40**, 1-5.
- Van Zeijl-Rozema, A., Cörvers, R., Kemp, R. and Martens, P. (2008). Governance for sustainable development: a framework. *Sustain. Dev.*, **16(6)**, 410-421.
- Wang, J. (2010). A game theoretical analysis of implementation of cleaner production policies in electroplating industry. Master of thesis, University of Harbin Institute of Technology, Harbin, China. (In Chinese with English Abstract)
- Wang, Y. (2007). Combining data mining and game theory in manufacturing strategy analysis. *J. Intell. Manuf.*, **18**, 505-511.
- Williams, P.T. (2005). Waste treatment and disposal. 2nd ed, Chichester: John Wiley & Sons. pp.127-130.
- Wills, R. and Finney, B.A. (2004). Environmental systems engineering and economics. Dordrecht: Kluwer Academic Publishers.
- Wilson, B. (2001). Soft systems methodology: Conceptual model building and its contribution. Chichester: John Wiley & Sons.
- Zhao, R., Neighbour, G., Deutz, P. and McGuire, M. (2012). Materials selection for cleaner production: An environmental evaluation approach. *Mater. Des.*, **2012**, 37,429-434.
- Zhao, R., Neighbour, G., McGuire, M. and Deutz, P. (2013). A computer based game theory simulation for cleaner production: An interplay between manufacturers and government. *J. Loss. Prevent. Proc.*, **26**, 59-67.
- Zhou, G., Jiang, P. and Huang, G. Q. (2009). A game-theory approach for job scheduling in networked manufacturing. *Int. J. Adv. Mfg Technol.*, **41**, 972-985.