Journal of Optimization in Industrial Engineering, Vol.11, Issue 2, Summer and Autumn 2018, 119- 127
DOI: 10.22094/joie.2018.622.1400

A Novel Model for the Analysis of Interactions Between Governments and Agricultures in a Study of Social Beneficial Externalities Based on the Stackelberg Game:A Case Study on Cotton production

Mohammad Ali Shafia[a,*], Sayyede Ashraf Moousavi Loghman[b], Aghdas Badiee[c], Kamran Shahanaghi[a]
[a]*Associte Professor, Department of industrial engineering, Iran University of Science and Technology, Tehran, Iran*
[b]*PhD. Student in Public Policy*
[c]*PhD. Candidate*
Received 16 May 2016; Revised 18 February 2018; Accepted 07 May 2018

Abstract

Production is a key economic activity with potential long-term social benefits realised thoroughly be can that only if governments comply with their duties towards domestic production. Governments are responsible for the production of sustainable agricultural products via appropriate allocation of subsidies and regulation of price policies that would help take advantage of the potentials underlying agricultural production. In this paper, a model is developed to investigate the interaction between two decision makers in the stackelberg game, government as leader and agriculture as follower, with the ultimate aim of providing benefits to all sectors in the society in the sustainable agriculture paradigm. The proposed model is validated and its efficiency demonstrated via a case study of cotton production as a strategic agricultural production. The model is first solved using a combination of fuzzy mathematical and grey quadratic programming methods to account for the inherent uncertainty in a number of problem parameters. The model is then analyzed against various government-producer interaction scenarios and finally, the analysis results are compared.

***Keywords*:** Government, Sustainable agriculture, Stackelberg game, Social benefit, Grey quadratic programming, Fuzzy programming

1. Introduction

In a suboptimal market situation where market outcome does not correspond to maximum efficiency in all sectors of the economy, resources are not perfectly allocated and demand and supply are imbalanced. This is caused by market failures which arise from having disregarded the benefit or drawbacks of actions for the society. Externalities are an example of market failure. A market fails whenever the actions of a party influence the outcome realized by another party without fully sharing or compensating for the outcome, be it negative or positive. Externalities can therefore be negative or positive and arise either from the production or the consumption of goods. In the presence of externalities in a competitive market equilibrium, governments have sufficient justification to intervene in the market with the aim of market failures correction and increasing the efficiency outcome. Governments consider costs and benefits of all actors in the economy rather than only the individual actors. Therefore, governments can ensure the consideration of both negative and positive externalities by regarding the supply or demand of certain goods as being too low or too high. Governments may then choose to target such market failures via the implementation of policies that encourage the production or consumption of goods with positive externalities and on the contrary, discouraging those with negative externalities (Hemels & Goto, 2017).

Agriculture is an inherently multifunctional economic sector with significant impact on the economy at various levels and also on the ecosystems (Climate, 1999) whereby government intervention is required irrespective of the developmental state of the country. Intervention of governments in the agriculture is in the form of subsidizing and taxing farmers, stabilizing the prices, imposing import tariffs and quotas, imposing restrictions on production, providing food subsidies for urban areas, supporting use of fertilizers, building irrigation systems, offering extension services, controlling marketing and finally, providing credit that is usually below market rates (Stiglitz, 1987).

Having laid out the above, a government-agriculture cooperation is justified for tackling market externalities. To address this issue, a mathematical optimization framework is presented that models government-agriculture interactions with the aim of redressing market failures. Here, agriculture is targeted as a private economic sector with positive externalities.

The remainder of this paper is structured as follows: a comprehensive review of the literature is presented in section two. The mathematical model of government-agriculture interactions is introduced in section three. A case study of cotton production is presented in section

*Corresponding author Email address: omidshafia@gmail.com

four to demonstrate the validity of the proposed model and its efficiency, in addition to elaborating the problem-solving method and reporting the analysis results. Finally, the study is concluded in section five.

2. Literature Review

Government-agriculture interaction involves a partnership between public and private institutions during which agreed goals are planned and implemented and associated costs, risks and benefits are simultaneously tackled (Schaeffer & Loveridge, 2002; Spielman & von Grebmer, 2006). Importantly, agriculture has undergone a change towards a sustainable paradigm in the recent decades as promoted by the EU (Wallace, 1994). European agriculture occupies around 40% of the land and as a result bears significant impact on the environment in rural areas in addition to also affecting the possibilities of using the environment (Baldock, Hart, & Scheele, 2009). Therefore, agriculture is a key element for creating public goods based on the natural environment (Z. Yang, Cai, Dunford, & Webster, 2014) and it is responsible for the provision of new utilities to the society which are of the nature of public goods (Kallhoff, 2014). These include water, air, biological diversity, landscape and food safety at the highest generalization level, all of which are categorized as common or merit goods (Buckwell et al., 2009) and can be an external effect of "regular" agricultural production. It should be noted that due to the multifunctional model of agriculture different subsets of public goods may be provided (Vatn, 2001). Given the paradigm shift, market failures in the model of sustainable agriculture are inevitable since the market does not evaluate public goods (Czyżewski & Majchrzak, 2017) and should be approached via the sustainable development paradigm. As a result, numerous studies are conducted to investigate the effects of government interventions in agriculture with the aim of market failures correction.

Generally, these studies can be divided into two categories: one category assess financial support and the other assessed non-financial supports. Many often high-income and developed countries hinder agricultural exports from developing countries by imposing high tariff rates on the imports. By providing domestic support to farmers, these high-income economies serve as detrimental to the survival of exporters in developing countries. In addition, many high-income countries grant subsidies to domestic agricultures. Large-scale internal support is undertaken primarily by OECD[1] countries, especially the EU, Japan and the United States. Industrialized countries exhibit 88% of the total domestic support payments (Hoekman, Olarreaga, & Ng, 2002). Also, other researchers suggest allocation of subsidies and regulation of price policies which impose both positive and negative long-term impact on domestic production, respectively. Subsidies are used to promote industrial development and support innovation.

So, agriculture is a key economic sector that delivers positive societal benefits for the society in the sustainable development paradigm, but that is often considered non-economic by the estimates of cost-benefit analyses. Provided the high-impact nature of the internal and external benefits of agriculture on both the economy and the society, government intervention is necessary in order to regulate the consequences of such effects. Alike traditional agriculture, sustainable agriculture provides food for the population and prevents harm or risk to the environment; however, it also aims to ensure economic benefit for the farmers. Therefore, it is a key requirement of sustainable agriculture that the incomes of farmers, as key players in agriculture, are enhanced (Cui, Wu, & Tseng, 2016). Governments can facilitate this requirement via granting subsidies to farmers. The optimal value of the subsidize can be estimated via system dynamics (Jeon, Lee, & Shin, 2015), standard investment models in corporate government theory (Rajan, 2012; Tirole, 2010; Wu, Zhou, Yan, & Ou, 2016) and bi-level programming (Shih, Cheng, Wen, Huang, & Peng, 2012).

In the present study, government-agriculture interactions are investigated in the context of a Stackelberg game approach in order to find the optimum interaction. A comprehensive review of the various games so far established between governments and different manufacturers is necessary. In the literature, the majority of games are set up for green supply chain and environmental safety. Table 1 outlines these studies based on a classification of players and solution approaches. As evident from Table 1, majority of research disregards the analysis of the positive consequences of production.

The Stackelberg game was chosen for a number of reasons. First, it is appropriately modelled by bi-level programming as a relevant model. A bi-level program is an optimization framework with nested structure in which a first optimization task embodies a second optimization task. The outer and the embodied optimization problems are generally termed upper level and lower level problems, respectively. In the context of a nested structure, a solution is only feasible for the upper level problem if it is an optimal solution for the lower level problem, rendering such problems difficult to solve. Bi-level optimization problems are often formulated as leader-follower problems in game theory and economics, where the leader's optimization task is modelled at the upper level and is constrained by the follower's optimization task at the lower level. Here, the leader-follower relationship is such that leader holds all the necessary information about the follower's potential reactions to any action it takes and the follower, on the contrary, observes the leader's actions to respond with optimal reactions. The solution of the Stackelberg game would allow the leader to predict reactions of the follower and devise optimal actions (Sinha et al., 2013). Second, Stackelberg game is a model with perfect information in which the two actors of the game are in unequal positions. Governments and agricultures have different positions in

[1] Organization for Economic Co-operation and Development.

the society and can therefore be considered leader and follower. Here, the initial move by the leader is subsequently followed by a reaction from the follower. Then, leader modifies its decisions based on the follower reactions. Advantages of bi-level programming in modelling government-industry interactions have been previously demonstrated for policy formulations (Bard, 1999).

The present work is novel in that no study to date investigated the interaction between government and agriculture as two actors of a Stackelberg game using mathematical models in the sustainable agriculture paradigm. Moreover, uncertain grey variables are used. Here, the conflicting objectives of the two game players necessitates application of the Stackelberge game. The Stackelberg game can be modelled as a bi-level problem in the static state and consists of two levels for the leader and follower (Bard, 1999). as already outlined above. Here, objectives of the leader and follower are given in levels one and two of the objective function, respectively. The proposed solution method can be used to solve bi-level problems for which all or some of the variables are integer values. Here, constraints can be either linear or non-linear, and non-linear objective functions are maximized at both levels. Moreover, tolerance in fuzzy membership functions and branch and bound algorithms for generation of pareto optimal solutions are utilized (Emam, 2006). Grey quadratic programming is used given a quadratic objective function at each level of the game where some parameters of the objective function are grey non-deterministic (Huang, 1994). To arrive at a final solution, combined grey quadratic programming and fuzzy programming are used in GAMS software.

Table1
Classification of government-producer games

Subject	Solution approach	Type of information	Type of game	Reference
Green supply chain	Nash equilibrium	Complete information	Static	(Ai & Shufeng, 2013)
mining enterprise	Nash equilibrium	Complete information	dynamic	(Duan, 2010)
Green supply chain	General solution of stackelberg game	Asymmetric information	Dynamic-Stackelberg , cooperative game	(Ding & Huang, 2012)
environmental economics	believe 0 evolutionary algorithm	Complete information	Dynamic-Stackelberg	(Sinha, Malo, & Frantsev, 2013)
Safety in supply chain	Nash equilibrium	Complete information	Static and dynamic	(Na & Fusheng, 2013)
Green supply chain management	Perfect Nash equilibrium		dynamics	(Sheu & Chen, 2012)
Energy Planning	Multi-Particle Simulated Annealing Algorithm		Static	(Raymond, 2010)
Cleaner Production	simulation		Static	(Zhao, Neighbour, McGuire, & Deutz, 2013)

3. Mathematical Model

Agriculture carries great potential for both the economy and the society. As stated earlier, government interventions in agriculture are inevitable. Governments are responsible for the regulation of prices and policies and should take actions so as to deliver agriculture potentials maximally. Some studies recommend the implementation of subsidy and tax policies, both of which impose positive and negative impacts on domestic production. To simplify the problem, strategies limited by financial incentives are studied only. Here, government and agriculture are leader and follower in the Stackelberg game. Agriculture aims to earn maximum profit at each level of the production line whereas government aims to minimize costs associated with losing the domestic market in competition with imported goods via providing sufficient support to domestic production and maximizing the production profit.

following Theassumptions underly the present problem:

* The considered goods are the products of domestic agriculture, leading to positive societal consequences.
* Government budget is dedicated to the production of goods that deliver economic added-value for the country. Also, optimum subsidies and taxes that yield the aforementioned target are determined.
* Decision making is independent for domestic (internal) and foreign (external) markets.
* Country's internal market is supplied with domestic and foreign agricultures, simultaneously.
* Cost of production is fixed.

* Tariff rates are specified for imported goods in response to differences in domestic and foreign production costs.
* Shipment cost is not considered for imported or exported goods.
* Goods are not stored in depots.
* The static Stackelberg model is presented in which time elapse for shipment of goods is not considered.
* The volatility of total demand in the internal market is uncertain.
* Prices of goods are proportional to their quality.
* There is no smuggling in the market.
* International FOB prices are used to estimate the values of exported and imported goods.
* Surplus goods are exported to foreign countries and international markets.
* Domestic agriculture products have priority over the foreign counterparts. Imports are allowed only in case of supply shortages.
* Data is collected over a one calendar year period.

Parameters and variables of the proposed bi-level model of government-agriculture interactions are as follows:

Parameters:
D: Total market demand
C: Production cost per unit of goods
TC: Total production cost
PIN: Domestic price of product
PFOB: International price of product
F: Maximum production capacity of agriculture in the presence of resource limitations
R: The subsidized fraction of the production cost
t1: Tax rate on production
t2: Tariff rate on imported goods

Leader decision variables:
PB: Government guaranteed rate of purchase
S: Subsidies sum granted to producers per unit of the product
G: Government revenue
ucd: Internal market cost competitiveness index
T: Total tax collected from production and import tariffs

Follower decision variables:
X: Binary variable: 1 in the presence of exports, 0 otherwise.
M: Binary variable: 1 in the presence of imports, 0 otherwise.
d(S): Sales in domestic agriculture in the first scenario as a function of the lead variable.
d(PB): Sales in domestic agriculture in the second scenario as a function of the lead variable.

Given the above-mentioned parameters and decision variables, two scenarios are laid out in the proposed model. The first scenario aims to regulate agriculture production by taking into account subsidies provided by the government. Objective functions of the first scenario are created by reviewing relevant models in the literature, selecting the candidate models and refining their parameters and interactions (Chen, Mai, & Yu, 2006; Van Long & Stähler, 2009) in accordance with the targeted problem. The upper level problem is given in equation (1) and the corresponding objective function and constraints for the government are defined as follows:

$$\begin{aligned} &\mathrm{M}ax(\mathrm{G}) = \mathrm{t}_1 * D * \mathrm{P}_{in} * X + t_1 * \mathrm{d}(S) * \mathrm{P}_{in} * M + t_2 * (\mathrm{D} - \mathrm{d}(S)) * \mathrm{P}_{FOB} * M - \mathrm{S} * \mathrm{d}(S) - (D - \mathrm{d}(S)) * \mathrm{P}_{FOB} * M \\ &St: \\ &S < r * C \\ &S, d(S) > 0 \end{aligned} \quad (1)$$

Upper level problem in the first scenario:
- The first, second and third terms in the proposed objective function represent government tax and tariff sums; the next term characterizes subsidies granted by the government and the final term characterizes losses incurred by the country upon import of foreign goods.
- According to the proposed constraint, a sum equal to or smaller than the specified fraction of the production cost can be granted to the agriculture sector by the government in the form of subsidies.

In the lower level problem, the producer profit objective function is maximized by subtracting the sales revenue in the internal and external markets from the costs of production. This is shown in equation 3. In this problem, the first constraint concerns production capacity in the presence of limited available resources and the second measures stability in the presence of internal and external competitors. Here, the cost competitiveness index in the internal market (Siggel & Ssemogerere, 2000) must be smaller than one as defined in equation (2):

$$uc_d = \frac{TC}{P_{in} * d(S)} \quad (2)$$

Lower level problem in first scenario:

In the second scenario, agriculture sector regulates its own production based on the sales price of goods guaranteed by the government in order to maintain and strengthen the country's internal market. The government objective function is similar to that of the first scenario, given in equation (1), except for the final term that the government seeks to minimize. This term holds the government responsible for compensating any differences in the market price of the product and its guaranteed sales price. The objective function and its constraints in the lower level problem of the scenario, given in equation (2), are identical to those in the first scenario (3).

$$\begin{aligned}
&Max(\pi) = P_{IN} * D * X + P_{in} * d(S) * M - C * d(S) + S * \mathrm{d(S)} + P_{FOB} * (d(S) - D) * \mathrm{X} - \mathrm{t}_1 * D * \mathrm{P}_{in} * X - t_1 * \mathrm{d(S)} * \mathrm{P}_{in} * M \\
&\mathrm{St}: \\
&d(S) < F \\
&\frac{TC}{P_{IN} * \mathrm{d(S)}} \leq 1 \\
&S, d(S) > 0
\end{aligned} \tag{3}$$

Upper level problem in the second scenario:

$$\begin{aligned}
&\mathrm{M}\ ax(\mathrm{G}) = \mathrm{t}_1 * D * PB * X + t_1 * \mathrm{d(PB)} * PB * M + t_2 * (\mathrm{D} - \mathrm{d(PB)}) * \mathrm{P}_{FOB} * M - \\
&(PB - PIN) * TD * X - (PB\ _\ PIN) * d(PB) * M - (D - d(PB)) * \mathrm{P}_{FOB} * M \\
&S, d > 0
\end{aligned} \tag{4}$$

Lower level problem in the second scenario:

$$\begin{aligned}
&Max(\pi) = P_{in} * D * X + P_{in} * d(PB) * M - C * d(PB) + P_{FOB} * (d(PB) - D) * \mathrm{X} - \mathrm{t}_1 * D * PB * X - t_1 * \mathrm{d(PB)} * PB * M \\
&\mathrm{St}: \\
&d(PB) < F \\
&\frac{TC}{PB * \mathrm{d(PB)}} \leq 1 \\
&S, d(PB) > 0
\end{aligned} \tag{5}$$

To ensure a match between the local solution and the global maximum, concavity of the function should be confirmed. For strict concavity, the Hessian matrix, H, should be negative definite (semi-definite) (Bazaraa, Jarvis, & Sherali, 2011) when the Sylvester criterion is used. Based on this criterion, a matrix is called positive definite if the determinants of all sub-matrices are positive (Brinkhuis & Tikhomirov, 2011). Conversely, the matrix is negative definite if the determinants of all sub-matrices are negative. In the first scenario, Hessian matrices are computed for the objective functions and negativity of their determinants are demonstrated. As depicted in the entries of Table 1, the objective functions of the first scenario in the proposed model are strictly concave. Concavity of the objective functions in the second scenario is similarly defined and computed. It can be ensured that the solution obtained by the software is optimum for this function.

4. Case Study: Cotton Production

Cotton production is addressed to investigate agriculture production in the country and also to validate the proposed model. Cotton is a renowned strategic yield worldwide. Cotton industry is supported by governments in many countries given its 1400 percent added value. Subsidies provided for the production of cotton aim to stabilize cotton production and its dependent industries. In the past, Iran was the largest producer and exporter of cotton worldwide. Today, however, the country is recognized instead as an importer of cotton. Therefore, cotton production in Iran today demands government support and the planning and the implementation of dedicated policies. To review the recent status of cotton production in Iran, data statistics were gathered from private institutions such as the General Administration Office for cotton and oilseeds under the Iranian Ministry of Industry, Mine and Trades and the Iranian Ministry of Agriculture Jihad over a time period spanning 21st march 2013 to 22nd march 2014. Model parameters and actual values acquired from the gathered data are given in Table 3. A number of parameters were modified within the allowed range. In this study, uncertain parameters are addressed via grey systems instead of fuzzy systems due to the nature of the collected data and the comparatively more suitable features that grey systems exhibit as outlined below (Y. Yang & John, 2003):

1. Greyness levels are defined for the entire set whereas fuzziness levels are defined for each individual member of the set separately.
2. The interval of grey numbers defined is directly related to the value of an underlying white number, i.e. domain of the white number equals the interval of grey numbers. On the contrary, the interval of a fuzzy set specifies the membership scope and is not directly related to the underlying object.
3. In a grey set, greyness is indicative of lack of knowledge about the data whereas membership in a fuzzy set is indicative of the degree of belief in given concepts.

4. Acquiring knowledge about grey numbers adds to their precision, i.e. grey numbers become white. On the other hand, since fuzzy logic is a measure of uncertainty, the extra knowledge adds to the certainty of the membership value instead. If an interval-valued fuzzy set is used, knowledge acquisition will lead to a narrowing of the interval which will eventually hit zero and result in precise membership, having said that the object itself would remain fuzzy.

Table 2
Computation of the Hessian matrix for the objective functions in the first scenario

Objective function	Requirement calculations	Hessian matrix
Eq (1)	$\frac{\partial G}{\partial d} = t_1 * P_{in} * M - t_2 * P_{FOB} * M - S + P_{FOB} * M$ $\frac{\partial^2 G}{\partial^2 d} = 0, \frac{\partial^2 G}{\partial S * \partial d} = -1$ $\frac{\partial G}{\partial S} = -d$ $\frac{\partial^2 G}{\partial^2 S} = 0, \frac{\partial^2 G}{\partial S * \partial d} = -1$	$H_1 = \begin{bmatrix} 0 & -1 \\ -1 & 0 \end{bmatrix}$
Eq(3)	$\frac{\partial \pi}{\partial d} = P_{in} * M - C + S + P_{FOB} * X - t_1 * P_{in} * M$ $\frac{\partial^2 \pi}{\partial^2 d} = 0, \frac{\partial^2 \pi}{\partial S * \partial d} = 1$ $\frac{\partial \pi}{\partial s} = d$ $\frac{\partial^2 \pi}{\partial^2 S} = 0, \frac{\partial^2 \pi}{\partial S * \partial d} = 1$	$H_2 = \begin{bmatrix} 0 & 1 \\ 1 & 0 \end{bmatrix}$

To conclude, grey numbers are numbers with unknown positions within a clear defined boundary giving rise to a set of candidate numbers which are collectively called the grey set. In this paper, demand uncertainty and market prices are modelled using the grey system theory.

Table 3
Objective function parameter values

Parameter	Actual value
D	120 to 150 thousand tons
P_{IN}	5500 to 6500 Rs per kg
P_{FOB}	1.9 to 2 US $ per kg
C	Rs 5,2710 Rs per kg
TC	5142857000000 Rs
F	250 thousand tons
R	0.4
t_1	0
t_2	6%

4.1. Interpretation of results

- Analysis of the first scenario: The government as market leader determines the guaranteed sales prices based on market uncertainty

The guaranteed sales price is greater than the market price by at least 5%. The maximum guaranteed sales price is calculated by updating the sales price of cotton in recent years. This maximum value is, thus, regarded as the maximum purchasing power of the government. Because of this, the guaranteed sales price of cotton is extracted for the years in which guaranteed purchase existed. Then, the current value for the guaranteed sales price is computed based on the inflation rates in the initial and current years. In this scenario, total market demand is considered 150,000 tons and market price is considered uncertain grey in the range of (5500, 6500) Rs. Software-derived results for the first scenario are depicted in Table 4. Here, the second and third columns show values of the optimized objective functions for the government and producer, separately and outside of the game, respectively.

In Table 4, values in the second column show that by disregarding the producer the government seeks to lower the guaranteed sales price of cotton. On the other hand, values in the third column show that by disregarding the government the producer seeks to increase the guaranteed sales price of cotton in its own favor. However, results of the Stackelberg game presented in the fourth column show that the production sum in the country could be much higher than values of the upper and lower level analyses in which the guaranteed sales price is determined by the optimization of government and producer separately. It is expected that due to the independent optimization of government and producer objective functions, the resulting increase in the guaranteed sales price would lead consequently to an increase in the production of cotton. In the Stackelberg game, the guaranteed sales price is determined between (68870, 74120) and the production rate is enhanced to supply all domestic demands.

- Analysis of the second scenario: subsidy is determined by government based on total demand uncertainty

In this scenario, the total rate of market demand is taken into account in the form of uncertain grey and in the range of (120000, 150000) thousand tons, respectively. Software-derived results for the second scenario are depicted in Table 5 in which the second and third columns show the values obtained for the optimized objective functions of the government and producer separately and outside of the game, respectively. This is similar to the arrangement of Table 4.

Table 4
Results of the first scenario

Decision variable	First level	Second level	Stackelberg game
Guaranteed purchasing price by the	(57750 , 68250)	(80000 , 80000)	(68870 , 74120)
Production sum in the country (thousand	(75353 , 89054)	(80927,80927)	(150000, 150000)

Subsidies can be useful for critical products in two ways. First, they provide the country's security for goods and second, they boost producer revenue. Therefore, providing subsidies to critical industries is a first step towards sustainable development. Here, optimization of the government objective function separately by disregarding the producer shows the tendency of governments to omit subsidy allocation altogether, thus, scaling down internal production capacity and supplying market demand predominantly via the import of goods. On the other hand, optimization of the producer objective function separately by disregarding the government reveals that the producer seeks to maximize the sum of subsidy it receives; here, the sum is raised to the maximum possible value of 21080 Rs. In the context of government-producer interactions in the Stakelberg game, optimized subsidy sums of (10263.85 and 6782.91) Rs. are obtained. So, imports are reduced to none in the presence of subsidy and all market demand is supplied entirely via domestic production.

Table 5
Results of the second scenario

Decision variable	First level	Second level	Stackelberg game
The amount of subsidy per production unit (Rs)	(0 ,0)	(2108,4 , 2108,4)	(678,291 , 1026,385)
The amount of production in country (thousand tons per year)	(12273 , 15793)	(120000 , 150000)	(120000 , 150000)

5. Conclusion

Production was studied as a key economic activity with potential long-term positive societal outcomes. Here, government-agriculture interactions were characterised via the implementation of proposed models in the context of a Stackelberg game with government and agriculture as leader and follower of the game, respectively. Efficiency and validity of the proposed model were demonstrated in a case study of cotton production. Uncertainty in a number of model parameters triggered the combination of fuzzy mathematical programming and grey quadratic programming for solving the final model. Finally, a number of different scenarios were designed and consequently analyzed. Analysis results of the two scenarios proposed for cotton production show that optimization of government-agriculture interactions would fulfil a number of social targets such as sustainable development, support domestic production and minimize foreign import rates. The optimized sum of cotton production was obtained in both scenarios via the determination of sales price of cotton guaranteed by the government and the allocated sum of subsidies, respectively.

In the present research, government and agriculture were the only game players. However, it should be noted that additional game players also exist who can impact the market. For instance, farmers can cooperate with environmental agencies or agribusinesses to achieve sustainable agriculture. Here, whom the farmers choose to cooperate with would depend on who offers a better income, i.e., if the agricultural business can offer a better income than the government subsidy, farmers are willing to cooperate. Therefore, a potential future research direction may comprise a multi leader-multi follower Stackelberg game or other more advanced market optimization methods for analysis of the agriculture market.

References

Ai, X., & Shufeng, G. (2013). A Game Model Between Governments and Enterprises in the Green Supply Chain of the Home Appliance Industry.

Journal on Innovation and Sustainability. RISUS ISSN 2179-3565, 4(1), 35-42.

Baldock, D., Hart, K., & Scheele, M. (2009). Public goods and public intervention in agriculture European network for rural development.

Bard, J. F. (1999). Practical Bilevel Optimization: Algorithms and Applications: Springer.

Bazaraa, M. S., Jarvis, J. J., & Sherali, H. D. (2011). *Linear programming and network flows*: John Wiley & Sons.

Brinkhuis, J., & Tikhomirov, V. (2011). *Optimization: insights and applications*: Princeton University Press.

Buckwell, A., Armstrong-Brown, S., Baldock, D., Bielenberg, N., Brouwer, F., & van Ittersum, M. (2009). *Risk Task Force on Public goods from private land*. Retrieved from

Chen, C.-H., Mai, C.-C., & Yu, H.-C. (2006). The effect of export tax rebates on export performance: Theory and evidence from China. *China Economic Review, 17*(2), 226-235.

Climate, E. a. T. D. (1999). *Cultivating Our Futures - Taking Stock of the Multifunctional Character of Agriculture and Land*. Retrieved from

Cui, L., Wu, K.-J., & Tseng, M.-L. (2016). Exploring a Novel Agricultural Subsidy Model with Sustainable Development: A Chinese Agribusiness in Liaoning Province. *Sustainability, 9*(1), 19.

Czyżewski, B., & Majchrzak, A. (2017). Market versus agriculture in Poland–macroeconomic relations of incomes, prices and productivity in terms of the sustainable development paradigm. *Technological and Economic Development of Economy*, 1-17.

Ding, B., & Huang, Y. (2012). Emergency Materials Supply Chain Coordination by the Joint Mechanism between Government and Enterprises. *Asian Social Science, 8*(8), 15.

Duan, T. (2010). *An analysis on mining production and policy risk: Game between Chinese local government and mining investor.* Paper presented at the 2010 IEEE International Conference on Advanced Management Science (ICAMS 2010).

Emam, O. (2006). A fuzzy approach for bi-level integer non-linear programming problem. *Applied Mathematics and Computation, 172*(1), 62-71.

Hemels, S., & Goto, K. (2017). *Tax Incentives for the Creative Industries*: Springer.

Hoekman, B., Olarreaga, M., & Ng, F. (2002). Reducing agricultural tariffs versus domestic support: what's more important for developing countries?

Huang, G. H. (1994). *Grey mathematical programming and its application to municipal solid waste management planning.*

Jeon, C., Lee, J., & Shin, J. (2015). Optimal subsidy estimation method using system dynamics and the real option model: Photovoltaic technology case. *Applied Energy, 142*, 33-43.

Kallhoff, A. (2014). Why societies need public goods. *Critical Review of International Social and Political Philosophy, 17*(6), 635-651.

Na, Z., & Fusheng, W. (2013). The game analysis of manufacturers' political connections on product safety in supply Chain: evidence from China. *Discrete dynamics in nature and society, 2013*.

Rajan, R. G. (2012). Presidential address: The corporation in finance. *The Journal of Finance, 67*(4), 1173-1217.

Raymond, R. T. (2010). Determining approximate Stackelberg strategies in carbon constrained energy planning using a hybrid fuzzy optimisation and adaptive multi-particle simulated annealing technique.

Schaeffer, P. V., & Loveridge, S. (2002). Toward an understanding of types of public-private cooperation. *Public Performance & Management Review, 26*(2), 169-189.

Sheu, J.-B., & Chen, Y. J. (2012). Impact of government financial intervention on competition among green supply chains. *International Journal of Production Economics, 138*(1), 201-213.

Shih, H., Cheng, C., Wen, U., Huang, Y., & Peng, M. (2012). Determining a subsidy rate for Taiwan's recycling glass industry: an application of bi-level programming. *Journal of the Operational Research Society, 63*(1), 28-37.

Siggel, E., & Ssemogerere, C. G. (2000). Uganda's Policy Reforms, Industry Competitiveness and Regional Integration: A comparison with Kenya.

Sinha, A., Malo, P., & Frantsev, A. (2013). Multi-objective Stackelberg Game Between a Regulating Authority and a Mining Company: A Case Study in Environmental Economics.

Spielman, D. J., & von Grebmer, K. (2006). Public–private partnerships in international agricultural research: an analysis of constraints. *The Journal of Technology Transfer, 31*(2), 291-300.

Stiglitz, J. E. (1987). Some theoretical aspects of agricultural policies. *The World Bank Research Observer, 2*(1), 43-60.

Tirole, J. (2010). *The theory of corporate finance*: Princeton University Press.

Van Long, N., & Stähler, F. (2009). Trade policy and mixed enterprises. *Canadian Journal of Economics/Revue canadienne d'économique, 42*(2), 590-614.

Vatn, A. (2001). *Transaction costs and multifunctionality.* Paper presented at the OECD Workshop on multifunctionality, Paris.

Wallace, A. (1994). Sense with sustainable agriculture. *Communications in soil science and plant analysis, 25*(1-2), 5-13.

Wu, T., Zhou, W., Yan, X., & Ou, X. (2016). Optimal policy design for photovoltaic power industry with positive externality in China. *Resources, Conservation and Recycling, 115*, 22-30.

Yang, Y., & John, R. (2003). *Grey systems and interval valued fuzzy sets.* Paper presented at the EUSFLAT Conf.

Yang, Z., Cai, J., Dunford, M., & Webster, D. (2014). Rethinking of the relationship between agriculture and the "urban" economy in Beijing: An input-output approach. *Technological and Economic Development of Economy, 20*(4), 624-647.

Zhao, R., Neighbour, G., McGuire, M., & Deutz, P. (2013). A software based simulation for cleaner production: a game between manufacturers and government. *Journal of Loss Prevention in the Process Industries, 26*(1), 59-67.

This article can be cited: Shafia, M. A., Moousavi Loghman, S.A., Badiee, A. & Shahanaghi, K. (2018). Novel Model for the Analysis of Interactions Between Governments and Agricultures in a Study of Social Beneficial Externalities based on the Stackelberg Game: A Case Study on Cotton production . *journal of Optimization in Industrial Engineering*. 11(2), 2018, 119-127**.**

URL: http://qjie.ir/article_539593.html
DOI: 10.22094/joie.2018.622.1400