

Research on the coordination mechanism between food supply chain system and external environment based on logistic model

JIANDONG LIU¹

Abstract. This paper upholds the ideology of building the food safety governed jointly by all sectors of the society on the basis of the market mechanism, government regulation, self-regulation and social supervision, tests the feasibility and evaluates the model of the original data through adopting the Logistic model and applying SPSS19.0. As a result, it is acquired that the incentive degrees of trust condition, information sharing condition and external environment on the food supply chain can be perceived as the order parameter of the coordination mechanism between the food supply chain system and the external environment. The trust mechanism can be established through completing the contract and completing the food safety reputation feedback, etc. the information sharing mechanism can be established on the basis of information sharing platform. Additionally, the incentive mechanism can be constructed through the information sharing incentive, tax deduction and exemption and other incentive methods.

Key words. Food safety, Food supply chain system, External environment, Logistic model, Coordination mechanism.

1. Introduction

The food safety has been arousing the increasing attention from the nation, society and the people. Through anatomizing the coordination mechanism between the food supply chain system and the external environment, this paper seeks to help all nodes of the food supply chain system with the appropriate selection of their respective role played and the obligations assumed in the food safety. Under the premise of guaranteeing the food safety, all nodes of the food supply chain system

¹Department of Economics and Management School, Tianjin University of Science and Technology, Tianjin, 300222, China

are able to acquire the maximum benefits so as to share the food safety with the government and the social public.

2. Food supply chain system and external environment

2.1. Food supply chain system

The food supply chain system is jointly composed by the elements being interacted with each other organically, including the supplier of agricultural inputs, producer of edible agricultural products, food producers, food operator, finance, material and information, etc. such system is perceived as the entirety with the specific environment, structure and function. The environment involved is basically the natural environment and the environment generated in the wake of realizing the systematic functions.

(1) Structure of food supply chain system

The food supply chain system is deemed as the syntrophic chain or net structure formed by the supplier of agricultural inputs, producer of edible agricultural products, food producers and food operator being organically interacted with each other through exchanging the capital flow, logistics, information flow, value flow and job flow. In this model, the orientations of capital flow, logistics, information flow, value flow and job flow are pointed at by the arrows.

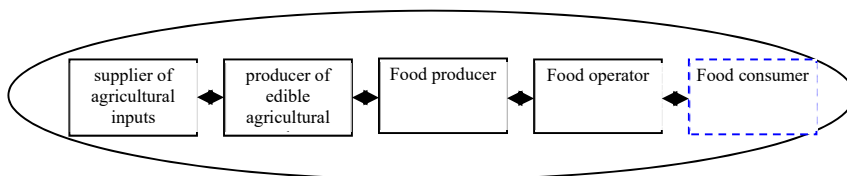


Fig. 1. Food supply system model

(2) Function of food supply chain system

The food supply chain system is functionalized to provide the safe food for the country, society and the consumers, and to energize the development of food industry and the development of socialist market economy.

2.2. External environment

The external environment of the food supply chain system includes government and social main-body. Additionally, the social main-body is mainly composed by three elements, including the third sector, consumer and public.

The government shall supervise and manage all nodes of the food supply chain system abiding by the relevant laws and regulations of the food. The government is deemed as the steersman to guarantee the national food safety and promote the development of food industry. The third sector refers to the social organization isolated from the governmental main-body and all nodes of the food supply chain system.

Furthermore, this sector, in virtue of its powerful professional skills, impartially supervises the safety of food, builds the food industry standard, and carries out the risk prevention and control of food industry. The consumers are the trigger of the food safety issues and the food safety incidents. In this paper, the consumers are deemed as the main-body of the external environment of food supply chain system. The public refers to the wider participants besides the government, the third sector and the consumers.

3. Coordination mechanism between food supply chain system and external environment and connotation of coordination theory

Under the coordination mechanism, the objective functions of food supply chain system and of external environment are consistent with each other. All sectors of the food supply chain system exert the positive influence on the food safety. All sectors of food supply chain system, government and social public, under the coordination mechanism function, shall acquire different benefits in accordance with different elements to be invested respectively as to realize the food safety. Through governing the food safety under the coordination mechanism between food supply chain system and the external environment, the defective food safety resource of the governmental supervision can be effectively made up, and the food market failure can be effectively resolved.

The system between the food supply chain system and external environment can be classified as the open system, complicated system and the self-organizing system. For this reason, the coordination theory can be adopted for research. The voluntary developing evolution between the food supply chain system and the external environment is powered by the competition and coordination among all sectors of food supply chain system, government and social public. The competition and coordination are two reverse states and tendencies. The competition is determined by the independence of all sectors of food supply chain system, government and social public. The coordination is determined by the order parameter between the food supply chain system and the external environment.

The coordination mechanism between the food supply chain system and external environment refers to the routine or regulation abided by all sectors of food supply chain system, government and social public decided by the order parameter as to realize the coordinated cooperation. The three-layer function is contained: the coordinated effect to realize the “ $1+1>2$ ” from quantity perspective among all sectors of food supply chain system, government and social public; new function and structure between the food supply chain system and external environment from quality perspective; the constant promotion between food supply chain system and external environment from the disordered condition to the ordered condition from the layer perspective.

4. Research of Logistic-based coordination between food supply chain system and external environment

The system between food supply chain system and external environment is complicated. The coordination mechanism formed on the basis of the nonlinear interactions and order parameter among all sectors of food supply chain system, government and social public fails to accurately express the mathematic relation. Additionally, the dependent variable determining whether the food supply chain system and external environment are coordinated with each other is deemed as the classified variable, rather than the continuous variable, viz. two categories of dependent variable, “yes” (coordination) and “no” (competition). The linear regression model fails to be adopted. For this reason, this paper seeks to analyze the coordination mechanism between the food supply chain system and external environment based on Logistic model, the log-linear model.

4.1. Theoretical foundation to analyze the coordination mechanism between food supply chain system and external environment based on Logistic

The existing continuous response variable y_i^* is set as the condition that food supply chain system and external environment are coordinated, and the range of y_i^* is regulated from negative infinity to positive infinity. As y_i^* surmounts a , the critical point making the objective function of food supply chain system consistent with that of external environment, the food supply chain system and external environment shall be coordinated with each other. Hence:

As $y_i^* \geq a$, the actual response variable $y_i = 1$

As $y_i^* < a$, the actual response variable $y_i = 0$

$y_i = 1$ indicates that the coordination is realized, and $y_i = 0$ bespeaks that the coordination is not realized. x_i refers to the independent variable influencing the realization of coordination: trust degree of food supply chain system and external environment, information sharing condition of food supply chain system and external environment, incentive from food supply chain system to external environment, and punishment of food supply chain system to external environment. Assume that the response variable y_i^* of coordination realization is linearly related to the independent variable x_i influencing the coordination realization:

$$y_i^* = a + bx_i + c_i . \quad (1)$$

Where c_i refers to the error members, hence:

$$P(y_i = 1 | x_i) = P[(a + bx_i + c_i) > 0] = P[c_i > (-a - bx_i)] . \quad (2)$$

Given that Logistic is symmetrically distributed, the formula (2) can be turned into formula (3):

$$P(y_i = 1 | x_i) = P[c_i \leq (a + bx_i)] = F(a + bx_i) . \quad (3)$$

Where F refers to the CDF (cumulative distribution function) of error member c_i . Under the model of Logistic, the variance of error member c_i is $\pi^2/3 \approx 3.29$. A relatively simpler formula shall be acquired by the CDF $F(a + bx_i)$ as:

$$P(y_i = 1 | x_i) = P[c_i \leq (a + bx_i)] = \frac{1}{1 + e^{-c_i}}. \quad (4)$$

Such formula is perceived as Logistic function. Error member c_i varies in the range from negative infinity to positive infinity. As the error member c_i tends to be infinitely negative, the Logistic function shall be $P(y_i = 1 | x_i) = P[c_i \leq (a + bx_i)] = \frac{1}{1+e^{+\infty}} = 0$; as the error member c_i tends to be infinitely positive, the Logistic function shall be $P(y_i = 1 | x_i) = \frac{1}{1+e^{-\infty}} = 1$. Accordingly no matter how c_i is valued, the value range of $P(y_i = 1 | x_i) = P[c_i \leq (a + bx_i)] = \frac{1}{1+e^{-c_i}}$ shall be between 0 and 1.

The formula (4) is concerted as follow:

$$P(y_i = 1 | x_i) = \frac{1}{1 + e^{(a+bx_i)}}. \quad (5)$$

The function presented is the CDF when c_i is valued as $(a + b_i)$. In the formula (5), c_i is defined as the trust degree of trust degree of food supply chain system and external environment, information sharing condition of food supply chain system and external environment, incentive from food supply chain system to external environment, and punishment of food supply chain system to external environment. It is the linear function influencing the realization of coordination between the food supply chain system and external environment.

$$c_i = a + bx_i. \quad (6)$$

In formula (6), x_i is set as the independent variable affecting the coordination realization. a and b are the regression intercept and the regression coefficient respectively. The conditional probability of coordination event realization is labelled as $P(y_i = 1 | x_i) = p_i$. The regression model of Logistic can be acquired by the formula (6):

$$p_i = \frac{e^{(a+bx_i)}}{1 + e^{(a+bx_i)}}, \quad (7)$$

p_i in the formula (7) refers to the probability of the i -th case realizing coordination. It is the nonlinear function able to be transformed into the linear function composed by the trust degree of trust degree of food supply chain system and external environment, information sharing condition of food supply chain system and external environment, incentive from food supply chain system to external environment, and punishment of food supply chain system to external environment. The specific transformation is presented as follows:

The conditional probability of realizing the coordination is defined as:

$$1 - p_i = 1 - \frac{e^{(a+bx_i)}}{1 + e^{(a+bx_i)}} = \frac{1}{1 + e^{(a+bx_i)}}. \quad (8)$$

Hence, the ratio between the probability to realize the coordination and the probability to not realize the coordination goes like:

$$\frac{p_i}{1 - p_i} = e^{(a+bx_i)}. \quad (9)$$

In view of formula (9), the ratio between p_i and $(1 - p_i)$ is perceived as the realization ratio of coordination event, referred as odds. The Odds shall be definitely valued positively as $0 < p_i < 1$, and it does not have the upper bound. A linear function can be acquired as Odds is valued as the natural logarithm:

$$\ln\left(\frac{p_i}{1 - p_i}\right) = a + bx_i. \quad (10)$$

Formula (10) is formed in Logit, and can be expressed as $Logit(y)$. What is attached importance to such transformation is that $Logit(y)$ is linear and dependent on the values of the trust degree of trust degree of food supply chain system and external environment, information sharing condition of food supply chain system and external environment, incentive from food supply chain system to external environment, and punishment of food supply chain system to external environment. The range of $Logit(y)$ is between the negative infinity to the positive infinity. As Odds is reduced from 1 to 0, $Logit(y)$ is valued negatively, and its absolute value grows increasingly. The probability evaluation of coordination realization surmounting the probability range of coordination realization shall not be considered in $Logit(y)$ because both a and b are the linear regression coefficients.

As there are k independent variable(s), the formula (7) can be extended as:

$$p_i = \frac{e^{(a+\sum_{k=1}^k b_k x_{ki})}}{1 + e^{(a+\sum_{k=1}^k b_k x_{ki})}}. \quad (11)$$

As there are k independent variable(s), the formula (10) can be extended as:

$$\ln\left(\frac{p_i}{1 - p_i}\right) = a + \sum_{k=1}^k b_k x_{ki}. \quad (12)$$

Where $p_i(y_i = 1 | x_{1i}, x_{2i}, \dots, x_{ki})$ is the probability of coordination realization between the food supply chain system and external environment, as the trust degree of trust degree of food supply chain system and external environment, information sharing condition of food supply chain system and external environment, incentive from food supply chain system to external environment, and punishment of food supply chain system to external environment are given.

4.2. Exploration of order parameter of coordination between food supply chain system and external environment

(1) Trust degree

The trust lays the foundation for the coordination. It can be deemed as the guarantee of the coordination. The trust involved hereof includes the trust of food supply chain system on external environment, and the trust of external environment on food supply chain system.

(2) Information sharing

Via the information sharing, the information asymmetry in the food market can be adequately alleviated, the disadvantaged position of consumer and public towards the food information can be effectively reversed, and the food market failure can be restrained.

(3) Incentive of food supply chain system to external environment

The food safety issue can be recognized as the economic issue. The food safety can be voluntarily guaranteed when the all sectors of the food supply chain system acquires the economic benefits after being incented by the external environment as much as that acquired by all sectors of food supply chain system through adopting the opportunism.

(4) Punishment of food supply chain system to external environment

The incentive and punishment are correlated with each other. If merely the incentive exists without the punishment, the food safety shall be entirely out of control. The government is able to optimize such condition through perfecting the laws and regulation and food safety standard, and elevating the operating efficiency of laws and regulations and the food safety standard.

4.3. Logistic model of coordination between food supply chain system and external environment

(1) Model specification

The basic form of Logistic model, $\ln\left(\frac{p_i}{1-p_i}\right) = a + \sum_{k=1}^k b_k x_{ki}$, is adopted, where p_i refers to the probability of realizing the coordination, x_{ki} refers to the influential factor influencing whether the coordination is realized, a refers to the intercepted member, and b refers to the linear coefficient of the influential factor.

Whether the coordination is realized is regulated as the dependent variable (y) which is valued as 0 or 1. 0 indicates that the coordination is not realized, and 1 refers to the status that the coordination is realized. Four variables are illustrated, including trust degree of trust degree of food supply chain system and external environment (x_1), information sharing condition of food supply chain system and external environment (x_2), incentive from food supply chain system to external environment (x_3), and punishment of food supply chain system to external environment (x_4). The specific variable features and the independent variable orientation influence are presented in the following table.

Table 1. Sample variable and explanation

Variable	Evaluation definition	Evaluation orientation
Dependent variable: whether the food supply chain system and external environment are coordinated with each other	The coordination is realized=1, not realized=0	
Explanatory variable: the trust degree of the food supply chain system and external environment	1 distrust; 2 normally trust; 3 highly trust	+
Explanatory variable: the information sharing condition of the food supply chain system and external environment	1 not sharing information; 2 sharing information; 3 highly sharing information	+
Explanatory variable: the incentive degree of the food supply chain system to external environment	1 not incented; 2 incented; 3 highly incented	+
Explanatory variable: the punishment degree of the food supply chain system on external environment	1 not punished; 2 punished; 3 highly punished	+/-

(2) Data source

These data are originated from the questionnaire. Totally 200 questionnaires are given out, and 162 of which are effectively collected, marking the effective questionnaire rate of 81%, surmounting the sample number required by the model. Through adopting the SPSS19.0 software, the feasibility of original data is tested. It is detected that the Cronbach's alpha reaches 0.81. For this reason, the original data is able to reflect the validity and veracity.

(3) Test of modeling result

Through adopting the software of SPSS19.0, the model is to be evaluated. The Enter approach is applied to the sample. In accordance with the SPSS19.0, the accuracy of the formula reaches 81.5%. The model evaluation results are listed as follows:

Table 2. Sample model evaluation result

	Regression Coefficient B	Exp(B)	Wald	.
Trust Degree X1	3.528	34.071	38.454	0.000
Information sharing condition X2	2.404	11.067	25.409	0.000
Incentive degree X3	1.213	3.362	11.099	0.001
Punishment degree X4	0.000	1.000	0.000	1.000
Constant A	-14.086	0.000	33.363	0.000

(4) Modeling result analysis

The significant levels of x_1 , x_2 and x_3 are basically less than 0.05. The significant level of x_4 is basically larger than 0.05. Variables including x_1 , x_2 and x_3 exert significant influence on the model. Additionally, the x_1 , x_2 and x_3 are the order

parameter of coordination between the food supply chain system and the external environment.

The trust degree of food supply chain system and the external environment (x_1)

The trust degree of food supply chain system and the external environment shall exert positive influence on the coordination realization. Under the condition of totally distrust, it has no way of realizing the coordination. Certainly the coordination shall be largely probable to be realized as there is merely the normal trust between the food supply chain system and the external environment. Furthermore, the total trust does not even exist practically.

The information sharing condition of food supply chain system and the external environment (x_2)

The information sharing condition of food supply chain system and the external environment shall promote the coordination realization between the food supply chain system and the external environment. All sectors of food supply chain system lack the original motivation to share information or encounter with the obstacle of information sharing. For this reason, the higher the information sharing condition is, the larger probability the coordination selection shall have.

Incentive degree of the external environment on food supply chain system (x_3)

The incentive degree of the external environment on food supply chain system shall exert positive influence on the realization of coordination. The food safety issues are perceived as the economic issues, and they are deserved to be resolved through adopting the economic principles. As the benefits gained through following the incentive mechanism are larger than those gained through opportunism, the food supply chain system turns out to be coordinated with the external environment.

5. Suggestion on constructing the coordination mechanism between the food supply chain system and external environment

While constructing the trust mechanism between the food supply chain system and external environment, information sharing mechanism between the food supply chain system and external environment and the incentive mechanism between the food supply chain system and external environment, the government shall play its steersman role to deepen the administrative machinery reform, proactively and effectively guide the third sector, consumer, public and all sectors of food supply chain to participate in the coordination, stably boost the construction of third sector, establish the information sharing platform, and accelerate the construction of overall traceability system of the food safety in virtue of the opportunity of transforming the governmental functions. The third sector shall make clear its obligation and responsibility, strengthen the self-construction and self-supervision, and build the virtuous cycle to be supplemented with government and to realize the mutual promotion. The consumer and public shall know the laws, understand the laws and use the laws and massively participate in the supervision of food safety. All sectors of the food supply chain system shall abide by the contract spirit, and make practical the self-entity responsibility, strengthen the self-supervision as to seek the innovation-based development.

5.1. Trust mechanism of food supply chain system and external environment

(1) Perfect contract

The trust is characterized by the uncertainty and risk. Contract is able to effectively prevent such uncertainty and risk. The practical operability and integrity of the contract shall be elevated, the cost of the opportunism shall be elevated, the emergency response ability towards the food safety issues shall be promoted, and the deterrent force towards the breach of law shall be strengthened. If the uncertainty and risk of trust are ignored, the trust itself shall result in the new food safety issues.

(2) Impartial and applicable national laws and regulation standard

The trust is characterized by the asymmetry, experience and infectivity. Any bias applicable to the standard of laws and regulation shall result in the loss of trust on the national public power. The foundation of trust shall be damaged.

(3) Establish and perfect food safety reputation feedback

The food safety reputation feedback can be perfected in various ways, as the government is able to issue the enterprise exempted from inspection and release the punished list, the third sector is able to issue the industry authentication and issue the blacklist of the industry, the media personnel is able to report the institution with the good reputation of food safety and expose the notorious institution of the food safety to the public.

5.2. Information sharing mechanism of food supply chain system and external environment

(1) Establish information sharing platform

Credit information system of all sectors of the

Based on the information sharing technology, the government shall establish and manage the information integration center as to construct the information sharing platform integrating finance, insurance, logistics and other services. The external information sharing hierarchy of the food supply chain system shall be determined by the system itself. The information sharing hierarchy of the food supply chain system and external environment shall be determined by the government. The information sharing platform shall mainly include the food supply chain system, risk prediction and prevention system of food safety, food safety information traceability system and the management system.

(2) Make the sharing prosperously through information sharing

Through the information sharing, all sectors of the food supply chain are able to elevate the precision for predicting the requirement and promptly respond to the market requirement. The government is able to better supervise and manage the food safety, boost the industrial and economic prosperity and development. The consumer and public are able to enjoy the better food safety.

5.3. Incentive mechanism and food supply chain system and external environment

(1) Information sharing incentive

The basis is to establish the information sharing platform, and the design of information sharing incentive method is attached great importance. The government and the third sector are able to jointly invite the food producer and food operator capable of representing the industry condition to analyze the policy of developing the food industry and industrial standard, and popularize the advanced production technology. The government shall play the leading role, and the third sector shall practically enter the enterprise of food producer and of food operator as to help them with the resolution of problems faced in the production and operation. The government shall play the leading role, and the third sector shall practically jointly establish the training and interning base and employment base with the enterprise of food producer and of food operator as to nurture the food personnel for the food industry development with proficiency in theory and practice.

(2) Tax deduction and exemption

The food supervision and management department of the government shall build the link with the tax department to deduce and exempt the tax for enterprise without the food safety issues for a long time, especially to deduce and exempt the tax of micro and small-sized food producing enterprise and the micro and small-sized food operating enterprise.

(3) Lowest purchasing price of agricultural insurance and edible agricultural products

The edible agricultural product producer in the food supply chain system is low in the organization degree and defective in the ability to resist the disaster. Hence, the poverty resulting from the natural disaster is commonly occurred. The lowest purchasing price of agricultural insurance and the edible agricultural products shall be adopted as to help the edible agricultural producer to alleviate the loss resulting from the natural hazard from the market value fluctuation.

Acknowledgement

The Ministry of Education Research of Social Sciences Youth Foundation of China under Grant No.14YJC630193, and the Ministry of Social Science of Tianjin Municipa Foundation of China under Grant No. 2012ZD044.

References

- [1] WANG YINGLUO: (2010) *System engineering* [M]. China Machine Press.
- [2] CHEN YANLI: (2012) *Market Failure, Demotivated Supervision and Multi-element Governance, A discuss of Chinese food safety issue* [J]. Journal of Harbin University of Commerce (Social Science edition).
- [3] XU LIANGPEI: (2014) *Research of coordination mechanism of agricultural product supply chain* [D]. Hubei Wuhan: Huazhong Agricultural University.

- [4] LONG-YING H U, YONG-QI C, JIANG Z S: (2007) *Research on the Coordination Mechanism Model of the Three-level Supply Chain*[C]// International Conference on Management Science and Engineering. IEEE Xplore, 2007:734-739.
- [5] SUN L, LI R, JU X: (2009) *Research on Coordination Mechanism Models of Launch Vehicle Supply Chain Based on Information and Contracts*[J]. 4:529-532.
- [6] SUN L, LI R, JU X: (2009) *Research on Coordination Mechanism Models of Launch Vehicle Supply Chain Based on Information and Contracts*[J]. 4:529-532.
- [7] LUO X N, SHI Y H, ZHU X Q: (2014) *Research on the Trust Coordination Mechanism in Supply Chain of Network Group Purchase Based on Game*[J]. Mathematics in Practice & Theory.
- [8] LI ZHIGANG, HUANG YAN: (2008) *Research on the Decision Model and Coordination Mechanism of Network Logistics and Distribution Based on Agent Technology*[C]// Management Innovation and Industrial Engineering for the Rise of Central China.
- [9] LV Q: (2013) *Research on Supply Chain Profit Coordination Mechanism Based on JIT Lot-Splitting*[J]. Advanced Materials Research, 694-697:3466-3471.
- [10] WANG J, WANG Q, SANG S: (2008) *Research on supply chain coordination mechanism based on fuzzy sale price*[C]// IEEE International Conference on Service Operations and Logistics, and Informatics, 2008. Ieee/soli. IEEE, 2008:2157-2161.
- [11] JIANG N T, GU Z: (2010) *Research on the Factors of Affecting Rational allocation of Supply Chain Residue under Coordination Mechanism*[J]. Logistics Engineering & Management.
- [12] TANG Q S, NIU T T, XIAN-TING M A: (2012) *The Coordination Mechanism of Quantity Discounts and Pricing Strategy about the Closed-loop Supply Chain MeR-CRM Based on Stackelberg Theory*[J]. Journal of Industrial Engineering & Engineering Management.
- [13] GAO A, XU P: (2012) *Research on agent-based purchasing coordination mechanism in enterprise supply chain*[C]// International Association of Management Science and Engineering Technology. 2012:717-724.
- [14] CHEN L H, WANG Y J: (2011) *Research on the Model of the Supply Chain Coordination Based on Principal-agent Mechanism*[J]. Logistics Engineering & Management.
- [15] YINGYUE ZHANG, QI LI, WILLIAM J. WELSH, PRABHAS V. MOGHE, AND KATHRYN E. UHRICH: *Micellar and Structural Stability of Nanoscale Amphiphilic Polymers: Implications for Anti-atherosclerotic Bioactivity*, Biomaterials, 2016, 84, 230-240.
- [16] JENNIFER W. CHAN, YINGYUE ZHANG, AND KATHRYN E. UHRICH: *Amphiphilic Macromolecule Self-Assembled Monolayers Suppress Smooth Muscle Cell Proliferation*, Bioconjugate Chemistry, 2015, 26(7), 1359-1369.
- [17] YINGYUE ZHANG, EVAN MINTZER, AND KATHRYN E. UHRICH: *Synthesis and Characterization of PEGylated Bolaamphiphiles with Enhanced Retention in Liposomes*, Journal of Colloid and Interface Science, 2016, 482, 19-26.

Received May 7, 2017