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Dynamic Evolution and Regulation of Vulnerability of Chemical Economic System

Zheng Zhou, Tao Wang

Wuhan University, Wuhan 430072, China
zhengzhou81293@163.com

In order to better avoid and adapt to the vulnerability of the Chemical economic system, this paper studies the dynamic evolution and regulation approach of such vulnerability. Taking a city in northeast China as an example, this paper analyzes the dynamic evolution of the vulnerability of the Chemical economic system using the neural network model and the comprehensive evaluation method and establishes a vulnerability evaluation model. The study finds that the vulnerability of the Chemical economic system is generally at a low level on a downward trend, showing that the vulnerability of the Chemical economic system is the main constraint to the sustainable development of the Chemical city. And the main influencing factors to the vulnerability of the economic system are the rigid industrial structure and the irrational investment structure.

1. Introduction

With the global climate changing, the vulnerability of the urban ecosystem has caused people's concern and become an important reference for analysis of regional sustainable development. Chemical resources are an important foundation for promoting social development, and Chemical economy is naturally the pillar industry of national economy. With the development of Chemical economy, Chemical cities emerged and developed. But as the Chemical resources exploitation continues, the vulnerability of the Chemical economic system has started to show.

Taking a city in northeast China as an example, this paper analyzes the dynamic evolution of the vulnerability of the Chemical economic system using the neural network model and the comprehensive evaluation method and establishes a vulnerability evaluation model.

2. Literature review

Regional Chemical economic system is a dynamic and complex system with many factors. Based on the complexity theory, the theoretical basis and practical basis for the analysis of regional Chemical economic system are as follows: At the level of factors, regional Chemical economic system involves many factors, such as capital, policy, technology, organizational form and so on. These factors interact and restrict each other and constitute very complex relation network. From the structural level, with the breakdown of the original Chemical supply and demand balance structure, Chemical economic system needs to form a new orderly structure through self-organizing and self-adaptive complex mechanism; and from the functional level, the overall function of regional Chemical economic system is realized through the coordination of subsystems. The Chemical economic system must balance the relationship between self-development and Chemical export. Chemical exploration and production in the Nigeria's Niger Delta region and export of oil and gas resources by the Chemical sector has substantially improved the nation's economy over the past five decades. However, activities associated with Chemical exploration, development and production operations have local detrimental and significant impacts on the atmosphere, soils and sediments, surface and groundwater, marine environment and terrestrial ecosystems in the Niger Delta. Ite et al. examined the implications of multinational oil companies operations and further highlights some of the past and present environmental issues associated with Chemical exploitation and production in the Nigeria's Niger Delta. Although effective understanding of Chemical production and associated environmental degradation was importance for developing management

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strategies, there was still a need for more multidisciplinary approaches for sustainable risk mitigation and effective environmental protection of the oil–producing host communities in the Niger Delta (Ite et al., 2013). El-Naas et al. developed and evaluated a novel three-step process for the treatment of highly contaminated refinery wastewater. The process consisted of an electrocoagulation cell, a spouted bed bioreactor with Pseudonymous putida immobilized in polyvinyl alcohol gel, and an adsorption column packed with granular activated carbon produced from agricultural waste, specifically date pits. The units were evaluated individually and as combinations with different arrangements at different operating conditions to treat refinery wastewater with varying levels of contaminants. The electrocoagulation cell unit was found to be effective as a pre-treatment step to reduce the large concentrations of COD and suspended solid and reduce the load on the bioreactor and the adsorption column. The results showed that the process was found to be highly competitive in comparison with other combined systems used in the treatment of industrial wastewater and can handle highly contaminated refinery or industrial wastewater with relatively wide range of operating conditions (El-Naas et al., 2014). Low-grade waste heat source accounts for a large part of the total industrial waste heat, which cannot be efficiently recovered. The ORC (Organic Rankine Cycle) system has been proved to be a promising solution for the utilization of low-grade heat sources. It is evident that there might be several waste heat sources distributing in different temperature levels in one industry unit, and the entire recovery system will be extremely large and complex if the different heat sources are utilized one by one through several independent ORC subsystems. In order to design and optimize a comprehensive ORC system to recover multi-strand waste heat sources, Song et al. put forward four schemes of the recovery system in continuous optimization progress. Moreover, they implemented further analysis from the view of economic factors and off-design conditions. The results showed that, by comparison, the scheme of dual integrated subsystems with R141B as a working fluid was optimal. The analytical method and optimization progress presented could be widely applied in similar multi-strand waste heat sources recovery (Song et al., 2014). The Lower Saxony Basin (LSB) in northwest Germany is one of the oldest oil‐producing basins in the world, where the first production well was drilled in 1864. It has been intensively investigated with respect to its hydrocarbon potential and can be regarded as a well‐studied example of a sedimentary basin that experienced strong inversion and uplift. Bruns et al. developed a fully integrated 3D high‐resolution numerical Chemical systems model incorporating the LSB, and parts of the Pompeckj Block in the north as well as the Münsterland Basin in the south. Aside from temperature and maturity modeling calibrated by a large amount of vitrinite reflectance and downhole temperature data, they also investigated Chemical generation and accumulation with special emphasis on the shale gas potential (Bruns et al., 2013).

Shale reservoirs have not benefited from advanced modeling tools to the extent of conventional resources. Thus an approach is proposed to integrate key parameters, such as total organic carbon (TOC) content, methane adsorption and organic porosity in a basin simulator. Romero-Sarmiento et al. calculated gas adsorption potential on organic material by using a Langmuir model, which accounts for pressure, temperature and remaining solid TOC. In addition, they also calculated organic porosity as the result of the change of the organic matter from solid immature kerogen to less dense fluid hydrocarbons during thermal maturation. At last, possible effects of assumptions made in the approach and perspectives are discussed (Romero-Sarmiento et al., 2013). Fiscal regimes describe all legislative, taxation policy, contractual, and fiscal elements under which Chemical operations are conducted in Chemical provinces or nations. There are far more Chemical fiscal systems worldwide than Chemical producing provinces. Iledare gave some explanations for this phenomenon, including the fact that contracts originating under several different fiscal regimes may be in effect at any given point in time. Other reasons cited included adoption of more than one fiscal arrangement during a licensing round, changes in political and economic conditions as well as in prospectivity assumptions of firms seeking the right to explore and develop Chemical resources, and the host government’s motivation to maximize economic rent collections from its country’s endowed resources (Iledare, 2014). Natural gas hydrate is a solid crystalline material composed of water and natural gas (primarily methane) that is stable under conditions of moderately high pressure and moderately low temperature found in permafrost and continental margin sediments. A natural gas hydrate Chemical system is different in a number of important ways from conventional Chemical systems related to large concentrations of gas and Chemical. Max and Johnson discussed continental margin sediments, including basin analysis to identify source and host sediment likelihood and disposition, potential reservoir localization using existing seismic analysis tools for locating turbidite sands, and deposit characterization using drilling and logging (Max and Johnson, 2014). Hunton Group cores from three wells that were examined petrographically indicate that complex diagenetic relations influence permeability and reservoir quality. Gaswirth and Higley pointed out that greatest porosity and permeability were associated with secondary dissolution in packstones and grainstones, forming hydrocarbon reservoirs. The overlying Devonian–Mississippian Woodford Shale was the major Chemical source rock for the Hunton Group in the field, based on one-dimensional and four-dimensional Chemical system models that were calibrated to well temperature and Woodford Shale vitrinite reflectance data (Gaswirth and Higley, 2013). Plays relying on the prolific Upper Jurassic – lowermost Cretaceous marine shales will continue to be the primary exploration targets in the North Sea but additional efficient Chemical systems in a mature oil province, such as the North Sea, are intriguing as they may constitute overlooked exploration potential. Petersen et al. pointed out that the coaly Middle Jurassic charged Triassic and Jurassic sandstone plays in the greater North Sea had shown to be economic viable with significant resources, such as the Culzean Field. Hence, the known coaly hydrocarbon occurrences and the shows in Middle Jurassic rocks demonstrate that the Middle Jurassic Chemical system had a regional distribution in Danish Central Graben which is encouraging for future exploration opportunities (Petersen et al., 2018). Okarah and Ndaguba assessed the implementation of the deregulation policy in Nigeria, with a focus on the Nigerian National Chemical Corporation. They also used informed knowledge in providing analysis for the study and they found out that the two major challenges inhibiting the implementation of the deregulation policy by the Nigerian National Chemical Corporation were price control, and effect of global market. The study recommended among others that, for Nigeria to realize its potential and reap the benefits of deregulating the sector, the Nigerian National Chemical Corporation must tailor the implementation of the policy in a manner that will take cognizance of the socioeconomic challenges facing Nigerians by recognizing and engaging community help services in communities where exploration takes place (Okarah and Ndaguba, 2015).

In summary, the above researches mainly studied the Chemical economic system, but there are few studies on the exploration of its dynamic evolution of the vulnerability and regulation approach. Therefore, based on the above researches, the principles and methods of the evaluation of vulnerability index of economic system are mainly introduced. In addition, the index system for vulnerability research of economic system is also discussed and the factors affecting the vulnerability of the economic system are analysed. The Chemical economic system is evaluated and the evaluation results show that the dominant factor of the vulnerability of the economic system is the ability of the system to deal with it.

3. Principle and Method

The vulnerability of the urban economic system is directly proportional to the sensitivity of the adverse disturbances in the system and inversely proportional to the system's ability to cope with adverse disturbances. The less sensitive the economic system of the Chemical city is to the changes in the recoverable Chemical resources, and the stronger coping ability the economic system has when facing the gradually depleting Chemical resources, the lower the vulnerability will be. Based on this, the evaluation model for the vulnerability of the economic system is constructed as ESV=f. (S, R), wherein ESV indicates the vulnerability of the economic system, S the sensitivity of the economic system, and R the coping ability of the economic system.

In this paper, the comprehensive evaluation method is used to calculate the vulnerability index of the economic system. The calculation formula is as follows:

$$ESVI_i = \sum_{j=1}^{n} w_i y_{ij}, i = 1,2\ldots,m; j = 1,2,\ldots,n \quad (1)$$

where, ESVIi is the economic system vulnerability index of the i-th research unit. The larger the value, the more vulnerable the economic system is; yij is the normalized value of the j-th evaluation index of the i-th research unit, and wj is the weight coefficient of the j-th evaluation index.

A Chemical city is a typical resource-based city emerging with the exploitation of Chemical resources. Its economic development is highly dependent on the recoverable Chemical resources, so the change of the recoverable Chemical resource reserve is the main disturbance factor affecting the urban economic development. Considering the indices selected should be scientific, typical, accessible and dynamic, based on the understanding about the vulnerability of the urban economic system, this paper selects two indices reflecting the dependence on Chemical resources and the foreign trade dependence to measure the sensitivity; and considers the economic, social and environmental aspects of the city in measuring the coping ability, particularly the sustainable development capacity. In the end, this paper uses 10 indices to form an index system for the vulnerability of the economic system (Table 1).

When the comprehensive evaluation method is used to evaluate the vulnerability of the economic system, the determination of the index weight coefficient will have a direct impact on the evaluation results. Since the data of each sample have been completely collected, this paper selects the entropy method commonly used in the objective weighting to determine the index weights. This method uses the inherent information of the evaluation indices to determine their utility values, thus avoiding the bias caused by subjective factors to a certain extent.

Table 1: Economic system vulnerability evaluation index system

Criteria layer	Index	Code	Weight
Sensitivity	Output value	S1	0.0988
	Proportion of employees	S2	0.0995
	Foreign trade dependence	S3	0.0985
Coping ability	Per capita GDP	R1	0.1017
	Local financial self-sufficiency rate	R2	0.0996
	Added value of the tertiary industry	R3	0.1018
	Three waste comprehensive utilization output value	R4	0.0998

There are complex nonlinear relationships between the influencing factors to the vulnerability of the economic system and the components of vulnerability, which is one of the problems for traditional evaluation methods. For the model construction, this paper uses the BP artificial neural network model to predict the data in future years. The 3-layer BP neural network is trained with the input and output sample sets, so that it can learn and adjust its hidden layer and nodes to implement the given input-output mapping relationship. Finally the data are substituted into the vulnerability evaluation model to predict the development trend of the economic system. The BP neural network structure designed in this paper consists of 10 inputs, 10 outputs and 1 hidden layer, and the hidden layer consists of 3 nodes. The flow chart of the BP neural network algorithm is shown in Figure 2.

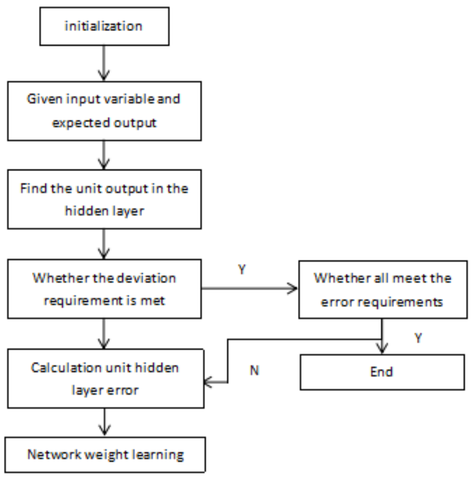

Figure 1: BP neural network algorithm flow chart

At present, there are few research results about the vulnerability of the urban economic system and the grading of vulnerability. By reference to the existing research results, the equal-interval grading method is used to divide the index value of vulnerability into 5 groups in the range of (0,1) (see Table 2).

Table 2: Grades for the economic system vulnerability

ESVI	ESVI<0.2	0.2≤ESVI<0.4	0.4≤ESVI<0.6	0.6≤ESVI<0.8	0.8≤ESVI<1.0
Grade	Low vulnerability	Lower fragility	Moderately vulnerable	Strongly vulnerable	Vulnerable strength

4. Results and analysis

After the weight coefficients are determined, the product of the weight value of the index and the normalized value of the index calculated according to the formula (1) is taken as the rating of the index, and then the rating of the economic system vulnerability is obtained through weighted summation. Through calculation, the economic system vulnerability indices of Daqing City from 2014 to 2017 are obtained, which show the evolution characteristics of the economic system vulnerability (Figure 2). Generally, the vulnerability of the Chemical economic system was on a downward trend. During the study period, the vulnerability was at a moderate level for a long time, and then dropped significantly.

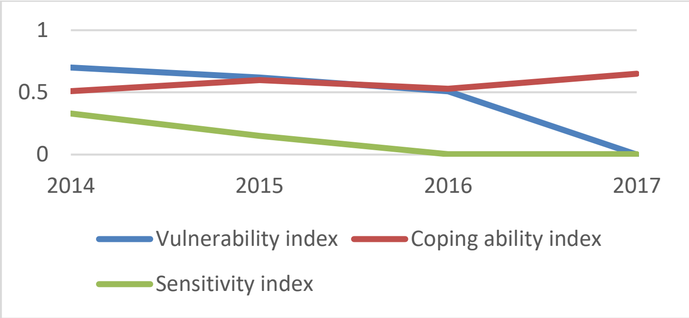

Figure 2: Vulnerability evolution of the Chemical economic system during 2014-2017

Table 3: Typical Chemical cities and their economic system vulnerability in 2017

	Type of development	Vulnerability index	Vulnerability level
Karamay	Mature	0.4240	Moderately vulnerable
Daqing	Mature	0.2826	Lower fragility
Panjin	Regenerative type	0.2759	Lower fragility
Fuyang	Declining type	0.2660	Lower fragility
Songyuan	Growth type	0.2485	Lower fragility
Dongying	Mature type	0.2139	Lower fragility

Table 4: Correlations between the economic system vulnerability of Daqing City and the evaluation indices

Ranking	Evaluation index	Correlation
1	Added value of the tertiary industry	0.4496
2	Proportion of output value of the mining industry	0.3674
3	Comprehensive utilization output value of three wastes	0.3364
4	Actual use of foreign capital	0.2912
5	Per capita GDP	0.2901
6	Fixed asset investment density	0.2811
7	Total retail sales of social consumer goods	0.2476

As can be seen from Figure 2, the sensitivity of the economic system in this city increased from 0.145 to 0.280, indicating that the sensitivity to adverse disturbances was generally on the rise, but it also experienced certain fluctuations, which can be divided into two phases: (1) from 2014 to 2016, it dropped with fluctuations from 0.145 in 2014 to 0.008 in 2016. This was a high-yield plateau period with an annual crude oil production capacity of over 5,000×104t, during which, the proportion of the output value of the Chemical mining industry dropped from 61.96% to 54.78%, and that of the workers engaged in Chemical mining fell from 42.70% to 21.54%. The city was at its mid stage of development, with a relatively high economic aggregate, which could greatly support the urban economic development and make the city less independent on the Chemical industry. Therefore, the sensitivity of the economic system was declining. (2) 2016-2017 was a sensitive rapid growth stage mainly because the recoverable reserves of crude oil were reduced and the mining became more difficult after the continuous production of crude oil at a capacity of 5,000×104t. The evaluation results show that the coping ability of the economic system is the governing factor to the vulnerability. In recent years, the city has actively adjusted its industrial structure, vigorously developed the petrochemical industry, extended the industrial chain, and at the same time actively developed the modern agriculture, equipment manufacturing, new energy and new materials, high-end services and other substitution industries, and as a result, the rigid industrial structure has been initially improved and the coping ability of the system against the adverse disturbances gradually enhanced.

In order to better understand the current status and development of the economic system in Daqing, this paper selects five other typical prefecture-level Chemical cities in China for comparison. It uses the evaluation model and the index system proposed to evaluate and compare the vulnerability of the economic systems (Table 3). According to the evaluation results, in 2012, the economic system vulnerability of Daqing was lower than that of Karamay, but higher than those of other four Chemical cities.

After calculation, the correlations between the economic system vulnerability index and the evaluation indices of Daqing are obtained. According to the analysis results (Table 4), the three indices most correlated with the economic system vulnerability index are the added value of the tertiary industry (R3), the proportion of output value of the mining industry (S1) and the comprehensive utilization output of three wastes (R5), indicating that the economic system vulnerability is highly correlated with the rigid industrial structure in the city.

5. Conclusions

The economic system vulnerability is the main constraint to the sustainable development of a Chemical city. This paper uses an evaluation model to analyze the data of the city, and finds that the sensitivity of the economic system to adverse disturbances is on an upward trend, and that its coping ability is also increasing, so the vulnerability of the economic system can be described as high sensitivity and high coping ability. The overall vulnerability shows a declining trend with fluctuations, and is currently at a low level. It indicates that this is the best transition period for Daqing. Through the gray correlation analysis, it is found that the main influencing factors to the economic system vulnerability are rigid industrial structure and irrational investment.

The main influencing factors to the economic system vulnerability vary in different periods. Therefore, the indices and the evaluation model proposed in this paper still need to be further improved and optimized, and the prediction of the economic system vulnerability also requires further studies. In future research, the author will analyze the coupling of the economic system, the resource environment system and the social system in the Chemical city and conduct comprehensive study on vulnerability and sustainability.

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