Open Access Library Journal
2020, Volume 7, e6630
ISSN Online: 2333-9721
ISSN Print: 2333-9705

Effects and Choices of Environmental Pollution Liability Insurance in Provinces of China

Xinkuo Xu[1*], Chenyang Jiao[2]

[1]School of Finance, Capital University of Economics and Business, Beijing, China
[2]Suning Consumer Finance Co., Ltd., Nanjing, China
Email: *xxkuo@126.com, xuxinkuo@cueb.edu.cn

How to cite this paper: Xu, X.K. and Jiao, C.Y. (2020) Effects and Choices of Environmental Pollution Liability Insurance in Provinces of China. *Open Access Library Journal*, **7**: e6630.
https://doi.org/10.4236/oalib.1106630

Received: July 19, 2020
Accepted: August 18, 2020
Published: August 21, 2020

Abstract

China began a pilot application for environmental pollution liability insurance in 2008. Although implementation situations vary substantially in different regions in China, it is appropriate to test how much contribution pollution insurance may make to environmental risk mitigation and other factors. Based on an analysis of pollutant emissions and investment completed in the treatment of industrial pollution, we find that pollution liability insurance, both compulsory and voluntary, does not work as expected in reducing environmental pollution. The value of this insurance mainly lies on the concern of the government for victims in environmental disasters. Considering the high administrative costs, it is not proper to push compulsory insurance across the country indiscriminately. Thus, this paper further classifies all 31 provinces in mainland China according to their economy and pollution characteristics and establishes guidelines for adopting pollution insurance for each province. The result shows that compulsory insurance is unnecessary for most provinces, while voluntary insurance can match their needs better.

Subject Areas

Business Finance and Investment, Environmental Economics, Risk Management

Keywords

Environmental Pollution Liability Insurance, Emissions, China

1. Introduction

The goal of development often runs counter to environmental conservation, leading to a greater volume of environmental pollution incidents as China has experienced rapid economic growth over the past three decades. Having seen the

significance of environmental protection and considering the decrease in GDP growth, China needs to change its traditional development method and seek the power of the market rather than that of the government. As an important negative externality of manufacture and production, the increasing number of pollution incidents and massive pollution loads should be taken into consideration. As a result, many market-based instruments have been introduced in China, and Environmental Pollution Liability Insurance was one of these (Mol and Carter, 2006) [1].

Environmental pollution liability insurance, which emerged in industrialized countries in the 1960s, aims to protect insured companies from bankruptcy by leveling the risk and ensuring that pollution victims can be compensated after environmental accidents (Freeman and Kunreuther, 1997 [2]; Minoli and Bell, 2002 [3]). The practice of environmental pollution liability insurance in China involves the central government establishing guidelines, after which local governments work toward implementation of these guidelines according to their requirements. Thus, the difference between the local circumstances of different provinces has distinct consequences. Following the experience of developed countries, both compulsory pollution insurance and voluntary pollution insurance are adopted in different provinces of China. Some provinces, such as Jiangsu, are encouraging compulsory insurance, and a large environmental pollution insurance market is taking shape. By contrast, some provinces have remained in the initial stage, and some have not even begun pilot work.

The result of the trial application shows that compulsory pollution insurance promotion leads to a better implementation condition than voluntary pollution insurance in present-day China (Yan and Mol, 2014 [4]) because it is difficult to structure a large-scale pollution insurance market through voluntary enrollment, and in this case, the insurers will be exposed to high risks. Thus, pollution insurance needs regulation to enhance the demand (Kunreuther *et al.*, 2001) [5]. The measures government has implemented, such as the incomplete third-party environmental liability legal framework, limited law enforcement capacity and low levels of compliance, however, are far from sufficient (Van Rooij *et al.*, 2012) [6]. Meanwhile, the power of the market could also help expend the influence and efficiency of pollution insurance, both compulsory and voluntary. The financial derivative designed for China's environmental pollution liability insurance will strengthen the underwriting capacity of insurance companies, mitigate the compensation risks of insurers and reinsurers, and provide a new channel to transfer the risks of environmental pollution (Pu *et al.*, 2017) [7].

To control the risk of pollution incidents and minimize the damage, this new approach to environmental management has gained significant attention and support from the government and market. Nevertheless, some problems and obstructions have still surfaced during the pilot process of implementing environmental pollution liability insurance. According to studies published recently, scholars found that adverse selection and moral hazards are obvious in this type

of insurance. Environmental risk is the most important factor that affects the willingness to cover environmental pollution liability insurance. Given additional types of risks, a company will be more likely to purchase pollution insurance (Xie *et al*., 2014) [8]. Additionally, when a polluting enterprise has been insured, its risks are transferred; thus, the enterprise does not give sufficient attention to avoiding environmental accidents. Instead, it allows risks to emerge and accumulate without any prevention, which could reduce the management costs of the company but result in pollution incidents. Moreover, most companies covered by pollution liability insurance are minor enterprises, which have higher moral hazard risks than major companies (Biais *et al*., 2010) [9], which obscures the outcome.

Some scholars have studied the implementation of environmental pollution liability insurance in China. Two types of pollution insurance were compared, and the scale of the insurance market was used to measure the level of progress. All government documents about pollution insurance were collected to compare local policies in different areas. Additionally, some data analyses based on the number of insured companies and insurance products can be found (Zhou and Wan, 2009) [10]. An overview of the implementation of pollution insurance in China can be seen through these studies. However, few papers have used exact market data to examine whether environmental pollution liability insurance performs as expected in China. That is to say, it is not certain whether insurance has mitigated environmental pollution over the past few years. Moreover, due to the situations being distinct in different areas in China, various local policies and methods being implemented may also bear discrepancies. Thus, it is necessary to verify the effects of population insurance based on statistical data. The key point that this study will discuss is the result of proceeding with pollution insurance.

Aside from the environmental benefit of pollution insurance, there are still several factors embodying the value of the insurance. Although the following analyses show that the performance of pollution insurance was not as good as expected in some factors, it still functions in other factors and would generally benefit all. Thus, the implementation of pollution insurance should be determined carefully, and the operators should balance the costs and revenues of the pollution insurance. Moreover, this paper also discusses which type of pollution insurance, compulsory or voluntary, performs better.

The next section of this paper is as follows: Section 2 discusses the relationship between the main beneficiaries in pollution insurance, including the government, insurance companies, victims of pollution incidents and polluting companies. Section 3 in this paper lists the data and methods used in the following empirical analyses. In Sections 4.1 and 4.2, to figure out whether pollution insurance provides environmental benefits in China, an analysis of variance is used on Chinese pilot provinces. In Section 4.3, according to the results from the analyses, all 31 provinces in mainland China were divided into four groups by their area characteristics. Each group has its own guidelines in implementing

environmental pollution liability insurance. Section 5 and Section 6 are discussed, and the conclusion is presented separately.

2. Theory

To avoid the adverse selection and moral hazard, one of the most prevalent means adopted by insurers is verification for each company wishing to be insured. In the risk assessment, a group of technicians employed by insurance companies visit the potentially insured company, assist workers in identifying the practices that contribute to their pollution risks, and suggest the changes needed to reduce these risks (Kunreuther *et al.*, 2007) [11]. The local Environmental Protection Bureaus (EPBs) play key roles in the environmental pollution liability insurance system in China and help insurers cooperate with environmental consulting companies to employ environmental and engineering experts in assessing environmental risks. After the risk assessment, a risk report including the identification of key risks, risk level evaluation and risk control suggestions are sent to EPBs. These reports are helpful for sharing useful information between all stakeholders. EPBs then recommend the adoption of risk control measures to polluting companies, and the insurers start negotiations with polluting companies concerning the details of contracts, which include the risk coverage, premium rate, underwritten value, retroactive period and so on (Yan *et al.*, 2014) [12]. Obviously, the assessment requires that insured enterprises take steps toward management and impart methods and knowledge of control risks to those enterprises, which is likely to help decrease incidents. This improvement has been reported in Michigan, US, where a state-level government assurance program was switched to private insurance markets to finance cleanups and the frequency of underground fuel tank leaks was reduced by more than 20% (Yin *et al.*, 2009) [13]. Therefore, this is the main theory supporting mitigation of the environmental risk function of pollution liability insurance.

Insurance was invented as an economic compensation tool that was used in production and daily life from the beginning of industrial development. However, pollution insurance is somewhat different from normal insurance because it not only involves insurance applicants and insurers but also relates to victims in environmental pollution incidents. In addition, the government, which is also a stakeholder in this system, plays a vital role in the implementation. Because of the multi-element nature of related subjects, the expected revenue of pollution insurance is greater than the environmental return. Except the environmental effect, pollution insurance has benefited each subject in different dimensions, such as management, polity and economics (Katzman, 1988) [14]. All are listed in **Table 1**.

Government is the enforcer and supervisor of environmental pollution liability insurance, and it takes precedence over the entire insurance market. Evidently, pollution insurance offers considerable political profit. Since the duty of the government is to serve its citizens, the satisfaction of the citizens and the government's

Table 1. Benefits of pollution insurance for different subjects.

Subjects Benefits	Government	Insurance companies	Victims	Polluting companies
Political	√	×	×	×
Finance	√	√	√	×
Management	×	×	×	√

reputation are important. The pollution liability insurance provides extra security for people in potential environmental pollution accidents, which could reduce the remedy disputes caused by accidents. Those who are covered would be satisfied with the policy and more reliant on the government. Moreover, government also could gain potential economic profits. Because the damages are often significant and influence is wide once pollution incidents occur, polluters can scarcely afford payment for the victims and environmental recovery. Without pollution liability insurance, once a limited liability company announces bankruptcy, the government must undertake liability for the victims and environment. While the outcome will be different if the insurance existed, the liability can be transferred to insurers. Compared to the administrative costs of implementation, the cost of aftercare is much higher, so it is worth implementing pollution liability insurance if the government has significant pollution treatment pressure.

The insurance companies gain economic profit through pollution liability insurance. Accounting to the law of large numbers, when the number of insured increases sufficiently, the insurance companies can control the risk at an acceptable range and profit from selling the insurance (Hsu and Robbins, 1947) [15]. As a new type of property insurance, pollution liability insurance has a huge untilled market in China. This market is expanding rapidly, and insurance companies increasingly profit from this type of insurance. If economic profit is chosen as a measurement, there is no doubt that insurers benefit the most from pollution insurance. Although important questions increase as to the competitiveness of the particular market, this system still appears to have considerable benefits for all participating insurers (Faure, 2002) [16]. On the other hand, the intense competitiveness also urges these insurers to provide better pollution liability insurance products.

As mentioned before, another important reason it is necessary to implement pollution liability insurance is that it provides extra security for victims in environmental pollution accidents. The victims often were not able to obtain compensation because of bankruptcy or other reasons and then resorted to the local government for equity before pollution insurance was implemented. Insurance can offer the victims economic assistance and compensation immediately, which helps them recover from the accident more quickly rather than being trapped in endless lawsuits (Faure, 2002) [16].

For polluters, the production cost increases for purchasing pollution liability insurance. However, with the expansion of the insurance market, the premium

rate will decrease gradually, and the premium will not be an unbearable burden for business. On the other hand, taking out insurance is not a useless outlay without benefits for polluting companies. When an insurer assesses the environmental risks of an insured enterprise, experts advise the enterprise regarding pollution treatment. The actual benefit of this advice is difficult to measure quantitively, but it must improve the management more or less, which has a positive effect on business. Once pollution incidents have occurred, this insurance could cover some loss and share compensation liability, which helps insured companies avoid bankruptcy risk. This coverage is the most fundamental function of insurance and cannot be ignored.

It should be clear that not all potential theoretical benefits are seen. The doubtless benefits are minuscule, and some benefits, such as environment effects, are uncertain. Thus, there is a substantial divergence of opinion about the method of implementation. Most provinces prefer voluntary insurance, and less than ten provinces have adopted the compulsory insurance; the others are still undecided about this. Thus, this study aims to find a method to classify provinces in China. There is no doubt that compulsory insurance shapes the market rapidly. However, we cannot simply claim that compulsory insurance is better than voluntary insurance. A province should choose the type of insurance that is most suitable, and only in this way can insurance promote development. Implementing pollution insurance is a critical decision, so the provinces should be clear on how to proceed.

3. Data and Method

3.1. Data

Pollutant emission and treatment investment for pollution are main indicators believed to measure the pollution pressure of an area. Additionally, total population and gross regional product are two auxiliary indicators reflecting an area's economy development.

Due to the accessibility of regions' data, this study selects nine provinces as research subjects and then divides them into three groups. The voluntary group includes provinces that implement voluntary insurance, including Chongqing, Shanghai, Hebei and Zhejiang. The compulsory group includes provinces that implement compulsory insurance, including Jiangsu and Hunan. A group without insurance is set as a control, which includes Fujian, Henan and Jilin, all of which have not implemented pollution liability insurance.

Pollutant emissions are used to test whether the insurance had a significant effect on the environment. There are three main pollutants in the industry: waste gas, waste water and solid waste. Because of the change in the statistical method, the data for waste gas and waste water are deficient in the studied period. Only the industry solid wastes produced were adopted as being representative of pollutants. The year 2009 is set as base period. All data are calibrated by the base period.

Industry has long been one of the pillar sectors in China. The treatment of industrial pollution has been a key point of environmental protection work that measures the effect of pollution insurance. The investment scale in the treatment of industrial pollution directly reflects the pressure from environmental protection that an area faces. To avoid the difference in the gross regional industrial product exerting an influence, all investment values were divided by the gross industrial product of each region, after which we obtain a new variable called the "treatment product ratio" (TP ratio). All TP ratios of the nine provinces in the three groups, from 2009 to 2013, are calculated and listed.

Considering the administrative cost, this study uses principle component analysis (PCA) to offer all 31 regions in mainland China recommendations about the best insurance for each. In the fourth part, this study used population, gross regional product, investment completed in the treatment of industrial pollution, and emissions of industrial solid wastes in 2013 as the initial possible correlated variables.

This study bases all analyses on data in the China Statistical Yearbook, which is compiled by the National Bureau of Statistics of China.

3.2. Methods

3.2.1. Analysis of Variance

The analysis of variance (ANOVA) is used to test whether there are significant discrepancies between the three groups in this study. ANOVA is a statistical model used to analyze the difference between group means and their associated procedures. In the ANOVA setting, the observed variance in a particular variable is partitioned into components attributable to different sources of variation. In its simplest form, ANOVA provides a statistical test of whether the means of several groups are equal.

In a single-factor ANOVA, statistical significance is tested by comparing the F-test statistic

$$F = \frac{\text{Variance between groups}}{\text{Variance within groups}} \tag{1}$$

$$F = \frac{\mathrm{MS}(\text{Groups})}{\mathrm{MS}(\text{Error})} = \frac{\dfrac{\text{SSA}}{I-1}}{\dfrac{\text{SSE}}{N-I}} \tag{2}$$

where MS is the mean square, I is the number of treatments and N is the total number of cases. $I-1$, $N-I$ are the degrees of freedom for the F-distribution. Using the F-distribution is a natural choice because the test statistic is the ratio of two scaled sums of squares, each of which follows a scaled chi-squared distribution.

A statistical hypothesis test is a method of making decisions using data. A test result (calculated from the null hypothesis and the sample) is considered statistically significant if it is deemed unlikely to have occurred by chance, assuming

the truth of the null hypothesis. A statistically significant result, when a probability (p-value) is less than a threshold (significance level), justifies the rejection of the null hypothesis but only if the a priori probability of the null hypothesis is not high.

In a typical application of ANOVA, the null hypothesis is that all groups are simply random samples of the same population. When studying the effect of different choices of pollution insurance on similar samples of provinces, the null hypothesis would be that all choices have the same effect (perhaps none). Rejecting the null hypothesis would imply that different choices result in altered effects.

3.2.2. Clustering Based on PCA

The principal component analysis (PCA) is a statistical procedure that uses an orthogonal transformation to convert a set of observations of possibly correlated variables into a set of values of linearly uncorrelated variables called principal components. PCA can be thought of as fitting an n-dimensional ellipsoid to the data, where each axis of the ellipsoid represents a principal component. If an axis of the ellipse is small, then the variance along that axis is also small, and by omitting that axis and its corresponding principal component from our representation of the dataset, we lose only a commensurately small amount of information. (Jolliffe, 1986) [17].

In this study, we need to find two axes to fit the four initial variables. To find the axes of the ellipse, we first subtract the mean of each variable from the dataset to center the data and obtain a data matrix, X. k rows represent different years of the study, and the p columns yield a particular type of data.

Mathematically, the transformation is defined by a set of p-dimensional vectors of weights:

$$W_k = \left(w_1, \cdots, w_p\right)_k \tag{3}$$

which multiples each row vector X_i of X to a new vector of principal component scores

$$t_i = \left(t_1, \cdots, t_p\right)_i \tag{4}$$

given by:

$$t_{ki} = X_i \cdot W_k \tag{5}$$

In such a way, the individual variables of t is considered according to the data set successively inherited in the maximum possible variance from X, with each loading vector w constrained to be a unit vector.

The first loading vector w_1 thus has to satisfy:

$$w_1 = \arg\max_{\|w\|=1} \left\{\sum_i \left(t_1\right)_i^2\right\} = \arg\max_{\|w\|=1} \left\{\sum_i \left(X_i \cdot w\right)^2\right\} \tag{6}$$

Writing it in matrix form results in:

$$w_1 = \arg\max_{\|w\|=1} \left\{\|Xw\|^2\right\} = \arg\max_{\|w\|=1} \left\{w^{\mathrm{T}} X^{\mathrm{T}} Xw\right\} \tag{7}$$

Since w_1 has been defined to be a unit vector, it equivalently also satisfies:

$$w_1 = \arg\max\left\{\frac{w^{\mathrm{T}} X^{\mathrm{T}} X w}{w^{\mathrm{T}} W}\right\} \tag{8}$$

With w_1 found, the first component of a data vector X_i can then be given as a score in the transformed coordinates:

$$t_{1i} = X_i \cdot w_1 \tag{9}$$

The second component can be found by subtracting the first principal components from X.

$$X_2 = X - X w_2 w_2^{\mathrm{T}} \tag{10}$$

The loading vector that extracts the maximum variance from this new data matrix is found:

$$w_2 = \arg\max\left\{\frac{w^{\mathrm{T}} X_2^{\mathrm{T}} X_2 w}{w^T W}\right\} \tag{11}$$

The second component of a data vector X_i can therefore be given as a score in the transformed coordinates:

$$t_{2i} = X_i \cdot w_2 \tag{12}$$

We then have the two components "level of economy" and "level of pollution".

We graph the 31 provinces into a scatter diagram and use K-means clustering to classify them. K-means clustering is a method of vector quantization, originally from signal processing, that is popular for cluster analysis in data mining. K-means clustering aims to partition n observations into k clusters, in which each observation belongs to the cluster with the nearest mean, serving as a prototype of the cluster. In this part, we used SPSS to make K-means clustering based on the distance between the two components, and the number of clusters was set at four.

4. Results and Analysis

4.1. Effect of Pollution Insurance on Environment

As mentioned before, eight observed provinces are divided into three groups according to their implementation; the groups represent compulsory insurance, voluntary insurance and no insurance. Table 2 lists the standardized data of the amount of industrial solid waste emissions in the three groups, which shows the distinct trends of industrial solid waste emissions in different groups. The results of ANOVA are listed in Table 3. Table 3 shows that F-Value in the test is 0.8826, less than $F_{0.05}$ (2, 12) = 3.885, which suggests that the pollution level of all groups are random. In other words, enterprises emit pollutants as usual in the provinces that implement pollution liability insurance or not. Pollution insurance cannot benefit environment by reducing pollutants emission. Thus, the ANOVA of pollutant emission suggests that pollution insurance was not able to

affect pollution emissions and the government did not obtain environment benefits from the insurance.

The reason lies in small proportion of insured companies in most regions. Even in provinces with compulsory insurance, the pilot range is limited in some industrial parks and in several sectors. The manufacturing activity of heavy pollution industries could introduce a large amount of waste water and industrial solid wastes, which would have a dire impact on the environment when accidents occurred. Thus, this study also selected two key monitoring sectors for comparison before and after implementation, which could show us if the emissions of industrial waste changed substantially in these sectors since the compulsory insurance pilot started.

This study selects a manufacturer of paper and paper products (Figure 1) and a manufacturer of raw chemical materials and chemical products (Figure 2) in

Table 2. Industrial solid wastes produced in provinces with different pollution liability insurance types (standardized).

	Voluntary	Compulsory	No insurance
2009	1	1	1
2010	1.2151	1.1313	1.1169
2011	1.5081	1.5218	1.1468
2012	1.4926	1.4729	1.2849
2013	1.4522	1.4840	1.3486

Table 3. Result of the ANOVA analysis for the industrial solid wastes produced in the three groups.

SSA	SSE	SST	R^2	F	P-value
0.0737	0.5010	0.5747	0.1282	0.8826	0.4389

Note: The three groups are voluntary, compulsory and no insurance.

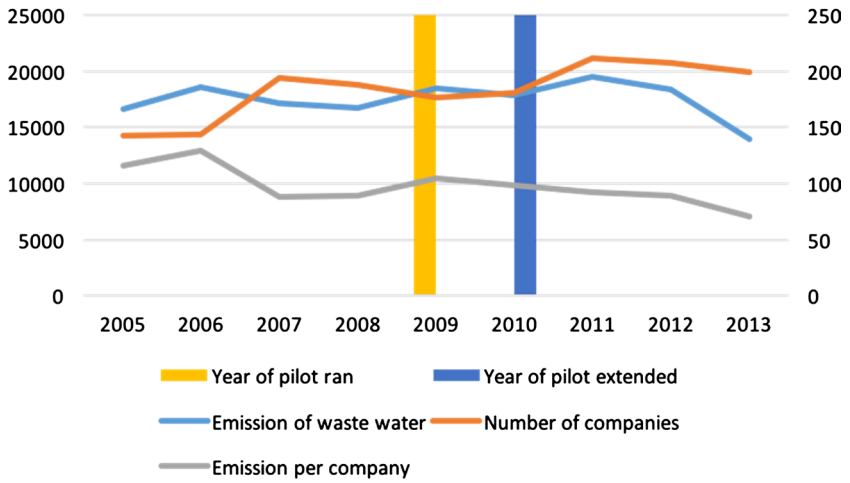

Figure 1. Emissions of waste water from a manufacturer of paper and paper products in Jiangsu Province (10000 tons).

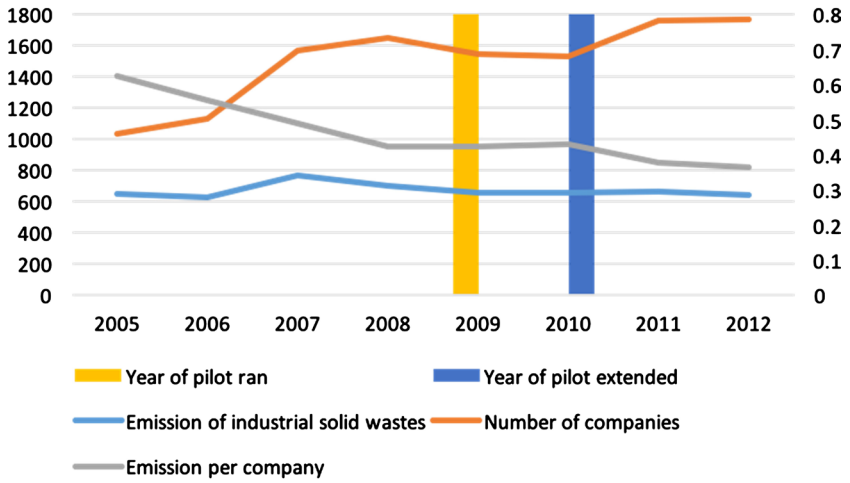

Figure 2. Emission of industrial solid wastes from a manufacturer of raw chemical materials and chemical products in Jiangsu Province (10,000 tons).

Jiangsu province for sector research. As it shows in Figure 1 and Figure 2, emissions sourced from both the paper sector and the chemical sector in Jiangsu province are on a downward slope from 2005 to 2013. However, emissions did not change substantially in 2009, when the pollution insurance pilot was run, and in 2010, when the local government issued a policy to extend pollution insurance dramatically. Therefore, the decrease of environmental risks in US appears invalid in China. We prefer to use technical progress and tighter supervision rather than pollution insurance to explain the decrease of emissions. We can also say that pollution liability insurance is only one factor that mitigates pollutants but is not the crucial one.

These results suggest that insurance does not cause enterprises to reduce pollutant emissions, so the question of why it is ineffective arises. To find a reasonable explanation, the next part focuses on investment in the treatment of pollution.

4.2. Effect of Pollution Insurance on Companies

The average TP ratios for five years in each group are listed in Table 4. To facilitate comparison, an ANOVA was used again in this section. ANOVA can show whether pollution insurance affected the local TP ratio or investment in the treatment of industrial pollution. The results of the ANOVA are summarized in Table 5. The F-Value in the test is 0.717844, which is less than $F_{0.05}$ (2, 12) = 3.885. This result suggests that there are no significant discrepancies between the three groups and that insurance has no effect on investment in the treatment of pollution. The local government cannot expect to ease the polluters' burden of investment in pollution controls by implementing pollution insurance. In this case, the R^2 is 0.107, which is too small to say whether there is a strong correlation between pollution insurance and investment in treatment. Insurance affects polluting companies slightly, and the investment in treatment changes so little that it is hardly observed.

Table 4. Average treatment product ratios of provinces with different pollution liability insurance types.

	Compulsory	Voluntary	No Insurance
2009	0.048437	0.068182	0.047469
2010	0.074676	0.077754	0.06642
2011	0.4005	0.084748	0.064677
2012	0.056087	0.07467	0.078219
2013	0.042968	0.06492	0.041764

Table 5. Result of ANOVA for environmental investment in different provinces.

SSA	SSE	SST	R^2	F	P-value
0.0116	0.0969	0.1085	0.1069	0.7178	0.5076

Several reasons could lead to this result and the most likely reason is that investment in the treatment of pollution also does not change substantially. Investment in the treatment of industrial pollution mainly comes from enterprise capital and bank lending in China. All investments are set and do not change substantially when an enterprise is established. The risk assessment required insured enterprises to take more steps toward management than investment in the treatment of pollution. Because the value of management is hard to quantify, this function of insurance can only remain theoretical. Methods for and knowledge of control risks were imparted to those enterprises, which have no influence on investment. Moreover, limited insured enterprises are also the probable reason that TP ratios suggest that pollution insurance did not make any difference in these pilot provinces.

This result could reveal the reason pollution insurance had no obvious effect on environmental protection. The measurement of the environmental effect is pollutant emissions, which comes from these polluting companies. To realize maximum profits, companies are unwilling to increase investment in the treatment of pollution because it would increase the cost of production. Since the implementation of pollution insurance does not affect the pollution-treatment investment of polluting companies substantially, pollutant emissions do not change substantially. Pollution insurance cannot influence on polluters' emission activity and thus has the little environmental benefit.

4.3. Provinces' Choice

Since it is clear that the value of pollution insurance is only apparent after relief rather than in preventions, governors need to consider implementing pollution liability insurance despite the high administrative costs. In pushing for a new policy such as this insurance, the government must coordinate a number of parties and establish numerous regulations and laws. Public resources are wasted if the area does not face severe environmental pressure. Therefore, in this part, we

take four economic and environmental indicators into consideration using PCA to offer each province guidelines on implementing pollution liability insurance. The four original indicators are, as mentioned in Part 3.1, population, gross region product, investment completed in the treatment of industrial pollution and emissions of industrial solid wastes in 2013.

The results of PCA are exhibited in Table 6. The component column denotes how many components can represent the original four indicators. The cumulative column denotes how much information from the original four indicators is inherited in this (these) component (s). According to the result, the cumulative percentage of the first two components is 88.819%, which suggests that the dimension reduction is reliable and that the two components reach a conclusion concerning the original indicators favorably. According to the component score matrix (Table 7), we can name the two new components. Component 1 can represent Total Population and Gross Regional Product better. The information of the two parts included in component 1 is greater than 90%, so we name the first component "level of economy". Naming component 2 is similar. The first two major weights of the original indicators are Industrial Solid Waste Produced and Investment Completed in the Treatment of Industrial Pollution, so we name this "level of pollution".

We now have two new indicators—level of economy and level of pollution—in provinces in mainland China, and these provinces are clustered by K-means. Figure 3 is the final result of PCA and K-means clustering. It is easy to find that the point closer to the top reflects the higher level of economics and the point closer to the right reflects the heavier environmental pressure. The first cluster of cases is located in the lower left area, which means that regions in the cluster are neither developed economically nor bears a heavy pollution burden. Therefore, these regions do not need to pay high administrative costs to implement compulsory insurance and voluntary insurance; even a no-insurance policy

Table 6. The cumulative percentage of all 4 components in dimension reduction.

Component	Cumulative (%)
1	66.779
2	88.819
3	97.255
4	100.000

Table 7. The score matrix of the first two components in dimension reduction.

Original indicator	Component 1	Component 2
Industrial Solid Wastes Produced	0.105	0.965
Total Population	0.903	0.252
Gross Regional Product	0.968	0.095
Investment Completed in the Treatment of Industrial Pollution	0.621	0.632

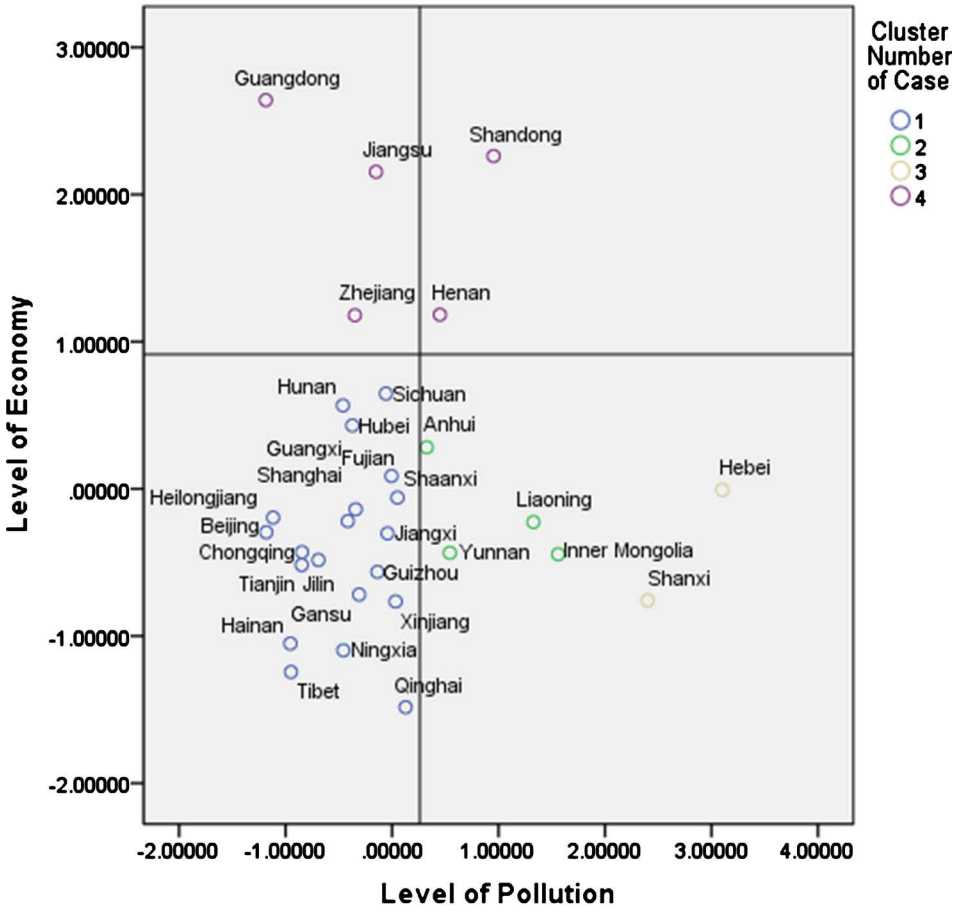

Figure 3. The result of the K-means clustering of the level of economy and that of pollution in provinces in mainland China.

is enough to match the demand of market.

The second cluster of cases is situated in the middle of the figure. The level of pollution in this cluster is higher than the first but is still at a normal value, so they also do not need to push this compulsory insurance in all industrial sectors and companies. Local governments need to adopt compulsory insurance in high-risk sectors and key point industrial parks. Aside from companies who are asked to buy compulsory insurance, others who believe pollution insurance is necessary can insure themselves voluntarily. The third cluster obviously has the highest pollution level across the country and should adopt compulsory insurance in their all industrial sectors. Under the highest environmental risk, the immediate compensation for the local residents should be guaranteed once environmental accidents have occurred. In the last case, regions in the fourth cluster are developed and are comparatively populous. Considering the dense population and high development level, despite the fact that the level of pollution in this cluster is not very high, environmental accidents result in significant loss. On the other hand, with their advanced economy, local governments have the capacity to implement compulsory insurance. Compulsory insurance is a wise choice for these provinces.

5. Discussion

5.1. Invalidity in Environmental Protection

From studies in different regions, it has become clear that pollution insurance does not have an obvious effect on environmental protection in China. Polluting emissions are not reduced notably, and internal reasons explain why insurance does not affect polluting companies' action. It was expected that a difference would be apparent in purchasing the insurance to mitigate pollutant emissions and realize environmental benefit. Unfortunately, the reality does not match the initial goals according to the data. Pollution insurance is not perfect and does not show its environment value in either the origin or result. Reluctantly, we must admit that pollution insurance is not helpful in environmental protection. A number of reasons will be discussed in the next section to explain why it does not work.

5.2. Reasons for the Invalidity

First, the pollution insurance market is not fully mature and needs more time to improve further in China. In most regions, insured companies were in the minority until now. In fact, the percentage of insured companies is less than 50%, even in provinces with the best implementation situation. Given these realities, the analyses based on the data of regions shows that pollution liability insurance has no acceptable effect.

Second, pollution liability insurance itself has limitations. Often, only financial compensation liability is covered in environmental accidents. When accidents occur, polluting companies face many indirect losses such as government sanctions and damage to reputation. These losses often cost much more than the compensation and can bankrupt a company. The risks transferred to insurers are so small that insured companies have little motivation to be covered. Thus, all polluting companies attempt to avoid any possible incidents, regardless of whether they have purchased pollution insurance. Last, pollution liability insurance is just one of numerous environmental protection measures and is far from mature. With a focus on only the function of pollution liability insurance, it is not surprising that it has limited impact on reducing environmental risks.

The third reason is the mismatch between risks and pollution in pollution liability insurance. Governors expect pollution liability insurance to play a positive role in environmental protection, but this has not been the case until now. However, high pollutant emissions are always accompanied by environmental risks, but the reality does not fit the intuition. Some sectors produce pollutant emission at a much higher rate than others, but thanks to effective risk management and advanced production methods, they can control environmental risks at a low level. On the contrary, regulators often overlook sectors who emits less pollutants so that they are more likely to accumulate risks and cause incidents. One typical example is the explosion in Tianjin on August 2015. The responsible company is a logistics company that did not emit any pollutant from its busi-

ness, but its warehouses of dangerous chemicals exposed the company to significant risks. With the breach of supervision, this accident killed hundreds and injured more. The victims in this accident turned to the government for help because the responsible company was not able to cover the losses. If pollution insurance were in place, the government would more easily share compensation responsibilities with the insurers, which is why the sectors in this study have not changed substantially since pollution liability insurance began implementation. They have controlled risks well under rigorous supervision, so expert advice from insurance companies do not substantially mitigating risk. Because implementation is limited in several sectors with high pollutant emission and because sectors that need expert advice most are not included, pollution liability insurance does not maximize its benefits in environmental protection.

5.3. Distinct Choice of Each Province

A conclusion that the pollution insurance is overestimated in China can be drawn according to the results. It cannot mitigate environmental risks as expected, so it is unnecessary to set standard criteria for all provinces to implement compulsory insurance. As a policy closely related to the environment, pollution liability insurance is sensitive to the situations of individual provinces and regions. Many factors, such as economic level, population and industrial structure, should be taken into consideration. China has a vast territory, and there is a great deal of dissimilarity from east to west. A one-size-fits-all approach is unscientific and unwise. Covering pollution liability insurance would undoubtedly increase the operating burden of companies. However, in provinces with few polluting companies, the number of insurance policies is not sufficient to observe the law of large numbers, so insurance companies have to set the premium rate at a high level to control risks, which will reduce the insured companies' enthusiasm for producing and make these companies less competitive in the market.

It is important to note that administrative costs are high when the government implements compulsory insurance because they need to cooperate with Insurance Supervision Bureau, Environmental Protection Bureau, insurance companies and so on. Moreover, many policy documents need government issuance, and supervision should be strengthened. All of these steps cost significant time and money. For some less developed regions whose burden of industrial pollution is small, the administrative costs are much higher than expected returns, and voluntary insurance appears to be a better choice. For some industrial provinces, who are under heavy pollution pressure, local governments should consider compulsory insurance, which can protect victims' rights and reduce disputes from pollution incidents.

6. Conclusions

This paper studies the effects of environmental pollution liability insurance in

China, analyzes the reasons and further analyzes the different choices of the provinces. The conclusions are as follows:

First, compulsory environmental pollution liability insurance could shape a mature market more quickly. Environmental pollution liability insurance is a mature approach to control environmental risks in western countries. Having seen the advantages of pollution liability insurance, the Chinese government introduced the concept to polluting companies as part of environmental protection action. The insurers, as the third party between polluters and government, played a key role in leveling the environmental risks and ensured that victims can be compensated immediately. The overview of the pollution liability insurance market shows that compulsory insurance performed better than voluntary insurance in terms of coverage rates.

Second, the expected function that pollution liability insurance can reduce pollutant emissions and mitigate environmental risks is not verified. To test the environmental effect of pollution insurance, this study selects pollutant emissions as the first indicator to create an analysis of variance. Because of the uncertainty of data, this result is for reference only and is not sufficient to draw a conclusion. Investment in the treatment of industrial pollution is taken into consideration in this research as well and shows that investment does not change substantially in provinces that implement pollution insurance. The result suggests that pollution liability insurance does not affect treatment investment of polluting companies, which means that polluters cannot reduce their investment in risk reduction measures by purchasing insurance and that insurance does not yield any financial profit to insured companies. A study of the sectors also showed that pollution insurance can influence the insured companies slightly in terms of pollutant emission, and the effect of environmental protection is also not evident. A number of reasons can be found to explain the result, but we find that pollution insurance does not work as expected in mitigating environmental risks in China. Compensation to victims mainly embodies the value of pollution liability insurance rather than environmental benefits.

Third, although voluntary pollution cannot shape a mature market as quickly as a compulsory one, it is suitable for most provinces in China. Based on the study, the government should realize that it is unnecessary to push compulsory insurance across China since its environmental benefit is so limited. Each province struggles with the one-size-fits-all implementation policy. The local government should adopt diversified measures in line with local conditions to develop pollution insurance. Provinces facing heavy pollution pressure and huge potential losses when accidents take place should firmly implement compulsory insurance. However, others should consider the high administrative costs of implementation when they make decisions. The existence of voluntary insurance has its purposes, so it cannot be rejected simply because it shaped a market more slowly than compulsory insurance. Local governments also need to adjust their approach in running policies. Some sectors that were ignored before but face

high environmental risks should be given sufficient attention. These areas sectors are significant potential areas for pollution liability insurance waiting for discovery. The work of local governments is the key to implementation. Policymakers should use their knowledge and awareness of local conditions to create a development plan that is most suitable for themselves. Pollution liability insurance can serve its proper purpose only in this way.

This paper contributes to the knowledge the effect of pollution insurance on environment in both theory and experience and it also provides some theory basis to the policy-making of pollution insurance for the government and insurance companies.

Acknowledgements

This work was supported by the National Natural Science Foundation of China (71603174) and the Fundamental Research Funds for the Universities Administered by the Beijing Municipality, Capital University of Economics and Business (CUEB) (QNTD202004). The authors are very grateful to have the paper manuscript reviewed by the journal editors and reviewers.

Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

References

[1] Mol, A. and Carter N.T. (2006) China's Environmental Governance in Transition. *Environmental Politics*, **15**, 149-170. https://doi.org/10.1080/09644010600562765

[2] Freeman, P.K. and Kunreuther, H. (1997) Managing Environmental Risk through Insurance. Kluwer Academic Publishers, Berlin. https://doi.org/10.1007/978-94-011-5360-7

[3] Minoli, D.M. and Bell, J.N.P. (2002) Insurance as an Alternative Environmental Regulator: Findings from a Retrospective Pollution Claims Survey. *Business Strategy and the Environment*, **12**, 107-117. https://doi.org/10.1002/bse.350

[4] Feng, Y., Arthur, P.J.M., Lu, Y.L., He, G.Z. and Van Koppen, C.S.A. (2014) Environmental Pollution Liability Insurance in China: In Need of Strong Government Backing. *AMBIO*, **43**, 687-702. https://doi.org/10.1007/s13280-013-0436-0

[5] Kunreuther, H.C., Mcnulty, P.J. and Kang, Y. (2001) Improving Environmental Safety through Third Party Inspection. *Risk Analysis*, **22**, 309-318.

[6] Van Rooij, B. (2012) The Compensation Trap: The Limits of Community-Based Pollution Regulation in China. *Social Science Electronic Publishing*, **29**, 701-745.

[7] Pu, C.Y., Addai, B., Pan, X.J. and Bo, P.T. (2017) Securitization Product Design for China's Environmental Pollution Liability Insurance. *Environmental Science & Pollution Research International*, **24**, 3336-3351. https://doi.org/10.1007/s11356-016-8172-1

[8] Xie, H., Li, Z. and Shen, M. (2014) The Analyses Based on Insured Willingness of Environmental Pollution Liability Insurance under Heteroscedasticity. *Population, Resources and Environment in China*, **24**, 84-90.

[9] Biais, B., Mariotti, T., Rochet, J.-C. and Villeneuve, S. (2010) Large Risks, Limited Liability, and Dynamic Moral Hazard. *Econometrica*, **78**, 73-118. https://doi.org/10.3982/ECTA7261

[10] Zhou, G.Y. and Wan, L.H. (2009) The Pilot Program in Environmental Pollution Liability Insurance and Relevant Issues. *Insurance Studies*, **5**, 95-98.

[11] Kunreuther, H.C., Pfaff, A. and Yin, H. (2007) Can Environmental Insurance Succeed Where Others Fail? The Case of Underground Storage Tanks. *Risk Analysis*, **31**, 12-24. https://doi.org/10.1111/j.1539-6924.2010.01479.x

[12] Feng, Y., Mol, A.P.J., Lu, Y., *et al.* (2014) Environmental Pollution Liability Insurance in China: Compulsory or Voluntary? *Journal of Cleaner Production*, **70**, 211-219. https://doi.org/10.1016/j.jclepro.2014.02.027

[13] Yin, H., Kunreuther, H. and White, W. (2011) Risk-Based Pricing and Risk-Reducing Effort: Does the Private Insurance Market Reduce Environmental Accidents? *Journal of Law and Economics*, **54**, 325-363. https://doi.org/10.1086/655804

[14] Katzman, M.T. (1988) Pollution Liability Insurance and Catastrophic Environmental Risk. *Journal of Risk and Insuranc*e, **55**, 75-100. https://doi.org/10.2307/253282

[15] Hsu, P.L. and Robbins, H. (1947) Complete Convergence and the Law of Large Numbers. *Proceedings of the National Academy of Sciences of the United States of America*, **33**, 25-31. https://doi.org/10.1073/pnas.33.2.25

[16] Faure, M. (2002) Environmental Damage Insurance in Theory and Practice. *Research in Law and Economics*, **20**, 283-328. https://doi.org/10.1016/S0193-5895(02)20015-9

[17] Jolliffe, I.T. (1986) Principal Component Analysis. Springer-Verlag, Berlin, 487. https://doi.org/10.1007/b98835