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Game Model of Logistics Risk Control for All Parties Involved in Cross-border E-commerce: Based on Insurance Rate Perspective

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Abstract:

As an emerging industry, cross-border e-commerce has a profound impact on the state economy, and cross-border logistics also plays an important role in it. Cross-border e-commerce carries logistics risks because of its features of long-distance distribution, cross-border, and multiple logistics nodes, and logistics has thus become a major bottleneck restricting the development of cross-border e-commerce. In review of related literature, this paper first identifies potential risks in cross-border e-commerce logistics, and then builds a logistics insurance mechanism model based on the dynamic game of incomplete information. The paper aims to analyze the positive effects of the logistics insurance mechanism on cross-border e-commerce logistics from multiple angles, find a feasible zone that can achieve multi-party win-win, and put forward policy recommendations on related logistics insurance compensation system.

Keywords*: Cross-border E-commerce, Logistics Risk, Insurance, Game Theory*

I. INTRODUCTION

In recent years, China has vigorously developed cross-border e-commerce to help traditional import and export companies and foreign trade enterprises achieve transformation and upgrading through the application of Internet technology. In 2015 and 2016, the State Council successively promulgated the Guidance on Promoting Healthy and Rapid Development of Cross-Border E-Commerce and the Notice on Revenue Policies for Cross-border E-Commerce Retail Imports issued on April 8, 2016. With good policy support, rapid development of electronic information technology and economic globalization, China's cross-border e-commerce has seen a rapid expansion. In 2016, cross-border e-commerce transactions amounted to 6.7 trillion, with an average annual compound growth rate of 31.6%.

Chen Tingxuan and Shang Yuming (2014)[1] analyzed the reasons for the rapid development of cross-border e-commerce in China, and believed that the momentum comes from the rapid development of technology, followed by the demand for cross-border e-commerce logistics; with the continuous growth of the cross-border e-commerce transactions, the corresponding demand for cross-border logistics will follow. The biggest difference between cross-border e-commerce and traditional domestic e-commerce lies in

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logistics. In fact, logistics efficiency is a pivotal link that guarantees the smooth and rapid cross-border e-commerce. Compared with traditional domestic e-commerce providers, cross-border e-commerce logistics has a longer cycle, higher costs, more nodes, and more complex flows. Currently, cross-border e-commerce progresses with the policy dividends, improving technologies and increasing demand. However, cross-border e-commerce is also faced with risks in the logistics process due to its complicated operation, participants and settlement currency types. Among them, the main obstacles mainly come from cross-border e-commerce logistics risks, including operational risk, payment risk, policy risk, etc. [1]. In addition, the operating level of cross-border transshipment logistics enterprises is varied and mixed, making cross-border e-commerce logistics facing more risks in terms of goods, payment, customs clearance, and transportation. The research results of Li Jiaqiao et al. (2013)[2] show that the main issues in cross-border e-commerce logistics include goods quality, logistics costs, and language fraud, while international price competition and international logistics model competition will negatively Chinese companies.

In review of related literature, this paper first identifies potential risks in cross-border e-commerce logistics, and then builds a logistics insurance mechanism model based on the dynamic game of incomplete information. The paper aims to analyze the positive effects of the logistics insurance mechanism on cross-border e-commerce logistics from multiple angles, find a feasible zone that can achieve multi-party win-win, and put forward policy recommendations on related logistics insurance compensation system.

II. LITERATURE REVIEW

There have been rich research results on cross-border e-commerce logistics risks at home and abroad. Zhang Bin, Liu Xiaojun, TaoZhang(2015)[3] analyzed the advantages, disadvantages, opportunities, and threats in the development of China's cross-border e-commerce logistics, and put forward related policy recommendations. Zhang Huan (2014)[4] interpreted the related policies of cross-border e-commerce logistics, and believed that the relevant policies had positive signals. Through the analysis of major risks, they proposed suggestions for the supervision of China's cross-border e-commerce logistics risks. Shi Quan (2013)[5] discussed the possible innovative models of cross-border e-commerce logistics, including the establishment of relevant risk monitoring policies and the rational use of free trade zones, with a view to proposing rational policy recommendations on cross-border e-commerce logistics supervision. Yan Shengyang (2014)[6] and Zhao Xiaojuan, Zhu Jianming(2015)[7] mainly studied the payment issues in cross-border e-commerce logistics, analyzed the related payment risks, and proposed the establishment of a more comprehensive cross-border e-commerce logistics payment system. Liu Min (2014)[8] analyzed the emerging opportunities arising from cross-border e-commerce logistics to the domestic express delivery industry, studied the overseas development of the domestic express delivery industry, studied the difficulties and obstacles of development, and made related proposals. Gao Xiang, Jiao Liangting (2016)[9] studied the transshipment in cross-border e-commerce logistics and believed that transshipment companies faced issues such as policy risk, legal analysis, and information risk. S Chong (2008)[10] analyzed the impediments in cross-border e-commerce logistics and found relevant reasons. E Gómez, B

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Martens, G Turlea. (2014) [11] used data from an online consumer survey panel on online cross-border trade in goods in a linguistically fragmented EU market and examined options available to policy makers to boost cross-border e-commerce in the EU Digital Single Market. In the research of risk control methods, there have been multi-border decision making method [12], and Bayesian method [13], a method of sustainability assessment and logistic risks identification [14], a supplementary policy on risk [15], and a method for risk control of cold chain logistics is proposed [16].

In terms of the analytical models used by scholars, Lima and Cordeiro (2017)[17] propose a new four-parameter lifetime model, called the extended log-logistic distribution, to generalize the two-parameter log-logistic model. The existence, stability, and asymptotic behavior of steady modes for a delay logistic equation with slowly varying coefficients are analyzed [18]. Seul Ki Kang, Liang Peng and Andrew Golub (2021) [19] proposes a random weighted bootstrap method to quantify the estimation uncertainty and an alternative two-step inference via weighted quantile regression.

In summary, most of the existing studies have given policy recommendations on the prevention of cross-border e-commerce logistics risk from the policy level, but fewer have adopted mechanism design to control or circumvent the risks, and no logistics risk control model considering insurance factors has yet been found. Based on the qualitative analysis of cross-border e-commerce logistics risks, this paper introduces a logistics insurance mechanism to establish the dynamic game of incomplete information model for cross-border e-commerce logistics, studies the multi-party win-win strategy under the logistics insurance mechanism, and finds a feasible solution that can achieve s multi-party win-win situation, providing reference and decision support for the promotion of the healthy development of China's cross-border e-commerce logistics companies.

III. RISK IDENTIFICATION AND MODEL ESTABLISHMENT

This section establishes a risk framework model for cross-border e-commerce logistics, which identifies the risks in the process of cross-border e-commerce logistics. First, environmental risk. Throughout cross-border e-commerce transactions, multiple parties will participate in, traversing multiple countries or regions. The differences in policies, economics and environment between countries and regions have a great impact on the smooth operation of cross-border e-commerce logistics. The second is market risk. When cross-border e-commerce logistics reaches other countries, it will face competition from local competitors. Meanwhile, due to the inflow of related products into other countries, the market share of competitors in other countries' related industries will be squeezed. The shopping and logistics habits of customers in other countries also cause corresponding logistics risks. The third is the risk of customs clearance. When the flow of cross-border e-commerce logistics is transferred to the customs clearance process, the problems faced by other countries are customs clearance and goods inspection. The policies vary in different countries, and cross border e-commerce logistics is particularly constrained by customs clearance policies. The fourth is transport risk. Cross-border e-commerce logistics involves more transportation modes and transport nodes, with more relevant parties. In the process of logistics circulation, it is inevitable that logistics risks will occur during operations such as transportation, loading and

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unloading, and sorting. The definition of relevant responsibilities, claims, and so on, all constitute the logistics risks in the transportation process.

This paper seeks to establish a cross-border logistics risk framework model in the general sense through the design of the logistics insurance mechanism. Through analysis, we can conclude that feasible zones that can avoid risks and achieve multi-party win-win. The model is assumed as follows:

Supposing a kind of goods is being operated in only one e-commerce supplier in country A. In order to sell the product overseas, the supplier entrusts country A's cross-border e-commerce logistics company - company M to export the product to country B. Supposing this supplier insures the cross-border e-commerce logistics in country A, then there are possible moral hazards of the cross-border e-commerce logistics company M insured in country A. Supposing country B's risk appetite is neutral, that is, country B has a linear utility function, company M's risk appetite is to avoid.

Supposing that in order to protect the domestic e-commerce, logistics insurance companies have the incentive to ensure that company M will not have cross-border logistics fraud, that is to ensure high-quality cross-border logistics services, rather than falsification or providing low-quality logistics services while claiming to be high-quality. Denote company M's logistics service quality variable as $c, \bar{c}$represents high logistics service quality of company M, and$\underline{c}$ represents low logistics service quality of company M.

Whether company M's cross-border logistics service is of high quality or low-quality can only be determined after product quality and customs clearance testing after the goods arrives at country B. If country B determines that company M's logistics services are of high quality. there are no moral hazards, then the e-commerce supplier from country A can successfully receive the full payment, which is set to be p. If company M's logistics service is deemed to be of low-quality, then country B has the right to choose to abandon the goods. At this moment, the e-commerce supplier from country A can only obtain liquidated damage r. This paper assumes that $p > r$. At the same time, it is assumed that once a cross-border logistics contract is concluded, neither party can negotiate a price, that is, either accept the goods to complete the transaction or reject the goods.

Based on the above hypothesis, set was the total price that country B is willing to pay, the value rules for w are as follows:

$$w = \begin{cases} \bar{w}, & \text{receive the goods} \\ 0, & \text{reject the goods} \end{cases} \tag{1}$$

Set p as the total price agreed upon in the cross-border logistics contract, r be the penalty in the form of a deposit, and the utility of country B in risk avoidance on cross-border logistics transactions is:

Receiving goods: $U_B = \bar{w}c - p$

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Rejecting goods (breach of contract): $U_B = -r$

Set n as the daily operating cost of the e-commerce supplier from country A. $\varphi(c)$as the cost to be paid in this cross-border logistics transaction. In case company M provides high-quality logistics services, $\varphi(\bar{c})$ indicates the cost to be paid by the e-commerce supplier from country Ain this cross-border logistics transaction; in case company M provides low-quality logistics services,$\varphi(\underline{c})$ indicates the cost to be paid by the e-commerce supplier from country Ain this cross-border logistics transaction, then $\varphi(\bar{c}) > \varphi(\underline{c})$. Based on the above hypothesis, it is easy to know that the utility of the e-commerce supplier from country A in cross-border logistics transactions is:

$$\pi_A = p - n - \varphi(c) \tag{2}$$

If the cross-border logistics company M of the e-commerce supplier from country A chooses riskavoidance, then the utility of the e-commerce supplier from country A can be set as:

$$U_A = f(p - n) - \varphi(c) \tag{3}$$

Where $f' > 0, f'' < 0, f(0) = 0$, if the e-commerce supplier is risk neutral, then $U_A = \pi_A$.

Supposing that there are two possibilities that country B refuses to accept the goods, resulting in the failure of cross-border logistics transactions. First, the transaction failure due to country B's own policy or national conditions, and the probability that country B rejects the goods is $\delta(0 \le \delta \le 1)$, the probability of receiving goods is $(1 - \delta)$. Then

Result	Probability
$W = 0$	δ
$w = \bar{w}$	$1 - \delta$

IV. ANALYSIS OF LOGISTICS RISK MODEL

Supposing that the e-commerce supplier from country A chooses risk avoidance, then the utility function is

$$U_A = f(p - n) - \varphi(c) \tag{4}$$

To avoid cross-border logistics risks, the e-commerce supplier from country A will insure the contractual price difference $(p - r)$ of the cross-border logistics contract. If the insurance premium rate requested by logistics insurance is equal to the payment failure rate δ, supposing that $\beta \in [0,1]$

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represents the insurance rate that the logistics insurance company can provide, then the e-commerce supplier from country A needs to pay the premium to the cross-border logistics insurance company as $\delta\beta(p-r)$; if $\beta = 1$, it means full insurance.

The utility of company M at this time is:

	Utility
Receiving goods	$U_A = f\big(p - n - \delta\beta(p-r)\big) - \varphi(c) = f_n - \varphi(c)$
Breach of contract	$U_A = f(\beta(1-\delta)(p-r) + r - n) - \varphi(c) = f_d - \varphi(c)$

Where:

$$f\big(p - n - \delta\beta(p-r)\big) = f_n \quad (5)$$

$$f(\beta(1-\delta)(p-r) + r - n) = f_d \quad (6)$$

If the insurance rate $\beta = 1$, then$f_d = f_n$, at this time company M has no incentive to provide high-quality logistics services. If company M chooses to provide low-quality logistics services, because $\varphi(\underline{c}) < \varphi(\overline{c})$ holds, then company M obtains the expected utility greater than the received goods from the rejected goods, then the increased probability of breach of contract ultimately leads to the difficulty of developing cross-border e-commerce logistics. Therefore, in general, $\beta < 1$ is required based on the principle of risk sharing.

Set the sequence of cross-border logistic transactions for the e-commerce supplier from country A, company M and country B as follows:

(1) The e-commerce supplier from country A enters into a cross-border logistics contract with country B, and agrees that the contract price$p, p > r$.

(2) The e-commerce supplier from country A chooses to insure or not according to the specific circumstances. If it insures, the premium rate is δ and the insurance rate is β.

(3) Company M is responsible for the cross-border logistics operations of the goods, providing high-quality or low-quality logistics services according to the situation.

(4) Country B refuses to accept goods with probability $\delta\ (0 \le \delta \le 1)$ and successfully completes the transaction with probability $(1-\delta)$ of receiving goods.

(5) If W is 0, for country B, refusing to accept the goods is the best choice. At this time, the transaction ends, B breaches the contract, the e-commerce supplier from country Aobtains corresponding claims from the insured logistics insurance in addition to liquidated damages; if $w = \overline{w}$, then B starts to determine company M's logistics service quality by testing the quality of goods and logistics process.

(6) The probability that country B finds the true logistics service for company M is ρ, and the

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probability of not finding is $1-\rho$.

There are two possibilities in country B's inspection process. First, company M is considered to provide low-quality logistics services, while country B refuses to accept goods; and second, company M is considered to provide high-quality logistics services, then country B accepts goods and pays in full payment. The conditional expectation utility function for the e-commerce supplier from country A and country B are:

$$E[U_A|c=\underline{c}] = (1-\delta)\rho[f_d-\varphi(\underline{c})] + (1-\delta)(1-\rho)[f_n-\varphi(\underline{c})] + \delta[f_d-\varphi(\underline{c})] = [(1-\delta)\rho + \delta]f_d + (1-\delta)(1-\rho)f_n - \varphi(\underline{c}) \quad (7)$$

$$E[U_A|c=\overline{c}] = (1-\delta)f_n + \delta f_d - \varphi(\overline{c}) \quad (8)$$

$$E[U_B|c=\underline{c}] = -r(\rho-\delta\rho+\delta) + (1-\delta)(1-\rho)(\overline{w}\underline{c}-p) \quad (9)$$

$$E[U_B|c=\overline{c}] = (1-\delta)(\overline{w}\overline{c}-p) - \delta r \quad (10)$$

The conclusion of contracts and the successful completion of cross-border e-commerce logistics need to meet an incentive compatibility constraint and two participation constraints, as follows:

Incentive compatibility constraint I CA:

$$E[U_A|c=\overline{c}] > E[U_A|c=\underline{c}] \quad (11)$$

Participation constraint PCA:

$$E[U_A|c=\overline{c}] \geq f(0) \quad (12)$$

$$\text{PCB}: E[U_B|c=\overline{c}] \geq 0 \quad (13)$$

From formula (13), we can conclude that the highest price that country B is willing to pay is determined by the PCB, that is, it needs to satisfy:

$$E[U_B|c=\overline{c}] = (1-\delta)(\overline{w}\overline{c}-p) - \delta r = 0 \quad (14)$$

It is easy to get

$$p = \overline{p} = \overline{w}\overline{c} - \frac{\delta r}{1-\delta} \quad (15)$$

If $\overline{w}$does not change, the highest price that country B is willing to pay is an increasing function of company M's logistics service quality, and it is a decreasing function of the payment transaction failure rate δ and liquidated damages r. That is, the higher the quality of cross-border logistics services provided by company M, the higher the price that country B is willing to pay. On the contrary, the higherδ or r, the

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lower the highest price that country B is willing to pay.

The smooth progress of cross-border e-commerce logistics must satisfy the utility requirements of all participants. It must also meet the price that e-commerce participants in cross-border e-commerce logistics are willing to pay, that is, it must meet both ICA and PCA constraints. Where the lowest price to satisfy the incentive compatibility constraint is given by:

$$E[U_A|c = \bar{c}] = E\left[U_A\middle|c = \underline{c}\right] \tag{16}$$

That is, $(1-\delta)f_n + \delta f_d - \varphi(\bar{c}) = [(1-\delta)\rho + \delta]f_d + (1-\delta)(1-\rho)f_n - \varphi(\underline{c})$

$$\text{Then } (1-\delta)\rho(f_n - f_d) = \varphi(\bar{c}) - \varphi(\underline{c}) \tag{17}$$

When the e-commerce supplier from country A is risk-neutral, there is:

$$f_n - f_d = p - n - \beta\delta(p-r) - \beta(1-\delta)(p-r) - r + n = (p-r)(1-\beta) \tag{18}$$

Get the lowest price for satisfying the incentive compatibility constraint

$$p = \underline{p}^{IC} = r + \frac{\varphi(\bar{c}) - \varphi(\underline{c})}{(1-\beta)(1-\delta)\rho} \tag{19}$$

From the above analysis, the following conclusions can be drawn:

(1) Since the insurance for cross-border logistics was insured, $(1-\beta) \leq 1$, the lowest price that satisfies the incentive compatibility constraint increases, and $\underline{p}^{IC}$ rises with the rise of β. That is, if the e-commerce supplier from country A has a higher degree of insurance coverage for cross-border e-commerce logistics, the premium payment amount will also be higher; on the other hand, the higher the degree of insurance coverage, the lower the price it can accept.

(2) p is proportional to $[\varphi(\bar{c}) - \varphi(\underline{c})]$, that is, the greater the cost difference between company M in providing high-quality and low-quality logistics services, the higher the lowest price for satisfying the incentive compatibility constraint, the smaller the price difference, the lower the lowest price that satisfies the incentive compatibility constraint.

(3) Increasing $\underline{p}^{IC}$ on the one hand can enable company M to provide high-quality cross-border e-commerce logistics services; on the other hand, improving $\underline{p}^{IC}$ will reduce the profits of the e-commerce supplier from country A, and thus in practice making some e-commerce companies choose to give up cross-border logistics insurance because of zero profitor low profit.

Supposing that the e-commerce supplier from country A chooses risk avoidance, then

$$\frac{d\underline{p}^{IC}}{d\beta} = -\frac{(p-r)[\delta f_n' + (1-\delta)f_d']}{(1-\delta)\beta f_d' - (1-\beta\delta)f_n'} \tag{20}$$

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From the mean value theorem, we know that there exists α between $[p-n-\beta\delta(p-r)]$ and $[\beta(1-\delta)(p-r)+r-n]$, so that:

$$f_n' - f_d' = (p-r)(1-\beta)f''(\alpha) \tag{21}$$

It is available that:

$$\frac{dp^{IC}}{d\beta} = \frac{(p-r)[\delta f_n' + (1-\delta)f_d']}{(1-\delta)[(1-\delta)(p-r)\beta f''(\alpha) + f_n']} \tag{22}$$

When $f'' < 0$, if the e-commerce supplier from country A has a higher degree of risk avoidance, then the formula is positive. At this time, the higher the insurance rate, the higher the lowest price that satisfies the incentive compatibility constraint, and the less incentivethe company M has to provide high-quality logistics services.

At the same time, satisfying the lowest price of the participation constraint also needs to satisfy the following equation:

$$PCA: E[U_A|c=\bar{c}] = f(0) \tag{23}$$

$$\text{That is, } (1-\delta)f_n + \delta f_d - \varphi(\bar{c}) = f(0) \tag{24}$$

Similarly, the relationship between the lowest price and the insurance rate satisfying the participation constraint is

$$\frac{dp^{PC}}{d\beta} = \frac{(1-\delta)f_n'(p-r)\delta - \delta(1-\delta)(p-r)f_d'}{(1-\beta\delta)(1-\delta)f_n' + f_d'\beta\delta(1-\delta)} = \frac{\delta(p-r)(f_n' - f_d')}{(1-\delta)\beta f_n' + \beta\delta f_d'} < 0 \tag{25}$$

That is, if the insurance rate is sufficiently high, the e-commerce supplier from country A will have the incentive to participate in cross-border e-commerce logistics transactions even for meager profits.

Through the above analysis, the price range in which the cross-border e-commerce transaction can proceed smoothly is:

$$\max\{\underline{p}^{PC}, \underline{p}^{IC}\} \le p \le \bar{p} \tag{26}$$

There are two types of equilibrium available:

	Conditions	Results
Equilibrium 1	$\underline{p}^{PC} > \underline{p}^{IC}$	Incentive compatibility constraint works
Equilibrium 2	$\underline{p}^{PC} < \underline{p}^{IC}$	Participation constraint works

The following figure shows the feasible zone for cross-border e-commerce logistics transactions:

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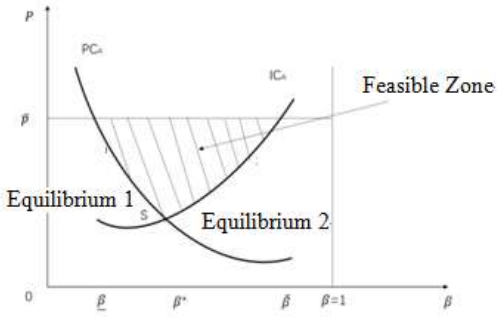

Figure 1: Feasible zone for cross-border e-commerce logistics transactions

In the above figure, $\bar{p}$indicates the highest price that country B is willing to pay, which is determined by PCB. It is a fixed value and is irrelevant to β; PCA indicates the relationship between $\underline{p}^{PC}$ and the insurance rate. Its value decreases with the increase of β. The ICA curve represents the relationship between$\underline{p}^{IC}$ and β of the e-commerce supplier from country A that chooses risk avoidance, the value decreases with the rise of β; β denotes the βvalue corresponding to the intersection of $\bar{p}$ and $\underline{p}^{PC}$. $\bar{\beta}$ denotes the β value corresponding to the intersection of $\bar{p}$ and $\underline{p}^{IC}$; β^* denotes the β value corresponding to the intersection point S of $\underline{p}^{PC}$ and $\underline{p}^{IC}$.

From the figure, it can be seen that cross-border e-commerce logistics transactions occur within $\beta \in [\underline{\beta}, \bar{\beta}]$. When $\beta \in [\underline{\beta}, \beta^*]$, there is a class 1 equilibrium where only PCA works. The rise of β will lower the lowest price, which will prompt the e-commerce supplier from country A to actively engage in cross-border e-commerce logistics transactions. And it will also enable the expansion of the cross-border e-commerce logistic transaction scope as it increases the expected profit of the e-commerce supplier from country A. In this case, if company M provides low-quality cross-border e-commerce logistics services, since β is small, it is not worthwhile to insure against the e-commerce supplier from country A because insurance cannot be covered because company M provides low-quality cross-border logistics services at its own losses. Therefore, when $\beta \in [\underline{\beta}, \beta^*]$, company M has the enthusiasm to provide high-quality cross-border e-commerce logistics services; when $\beta \in [\beta^*, \bar{\beta}]$, there is an equilibrium 2where only ICA works. With the increase of β, the lowest price will increase, which will prompt the e-commerce supplier from country A to actively engage in cross-border e-commerce logistics transactions, and it will also lead to a narrowing of cross-border e-commerce logistics transactions. In this case, if company M provides high-quality cross-border e-commerce logistics services, since β is high, it is worthwhile to insure against the e-commerce supplier from country A because the e-commerce supplier from country A can guarantee its own profit through logistics insurance. Then, since company M knows the insurance action of the e-commerce supplier from country A, it has incentive to deliberately provide low-quality cross-border e-commerce logistics services.

In summary, the value of β is a sensitive parameter for the entire cross-border e-commerce logistics

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transaction. A lower β value can facilitate cross-border e-commerce logistics transactions. At this moment, company M has to provide high-quality logistics service; however, extra high beta will play an anti-effect.

V. CONCLUSION

From the above analysis, it indicates that a cross-border logistics insurance institution or company should not provide a relatively high insurance rate when signing an insurance agreement. This is due to the fact that the higher underwriting ratio will force cross-border logistics providers to provide low-quality logistics services. From another perspective, the higher underwriting ratio will narrow the scope of cross-border logistics transactions. Combining China's current cross-border logistics insurance industry, the business is operated exclusively by China Cross-border Logistics Insurance Company. The company's relevant regulations stipulate that "the compensation rate for business risks caused by political risks or cases where the buyer refuses to pay is 90% of the invoice amount, and the compensation rate for cases where the buyer refuses to receive is 80%". Combined with the analysis of this paper, we can see that this ratio is obviously high, which will give rise to low-quality logistics services provided by cross-border logistics. Therefore, it is recommended that the relevant systems can reduce the rate of relevant claims appropriately.

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