Financial Service Based on Data Federation: An Application in Tobacco Supply Chain

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Objectives: We carry out governing research on the structure of the supply chain financing based on data federation, taking tobacco supply chain as an example so as to achieve the goal of establishing real-time, transparent and traceable supply chain financing. Methods:Based on the requirements of data federation, we use horizontal federation, vertical federation and transferfederation to build digital federation model,it is to realize the integrated credibility and risk control of supply chain financing. Results: Through data federation modeling, the data in the tobacco supply chain is linked. With complete data, financial institutions can remove invalid customers in the preliminary review process and effectively control the cost of credit review. Conclusion: The construction of supply chain financingtrust mechanism under data federation can optimize the lending data flow of theenterprises.

Key words: data federation; financial service; tobacco supply chain

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Promoting the capital liquidity of enterprises is the main focus of most of countries.At present, the theoretical model of supply chain financing is based on the fact that supply chain enterprises need to provide global data such as business electronic vouchers, logistics information flow, assets,etc. But the reality is that some enterprises are unwilling to share information for relevant stakeholders for the sake of operation security and privacy.The digital wave promotes financial institutions to carry out the digital transformation of enterprise financial services. Making accurate enterprise financial decisions under risk control and realize effective financial services under data dispersion,this is the goal of the current supply chain financing.

Since the data federation model was proposed in 2018, it has become a highlight in the field of machine learning and artificial intelligence. In the process of online learning, the data is not local, privacy is not disclosed, laws and regulations are not violated. Multiple participants cooperate with the data to establish a virtual common model for mutual benefit. Such data learning method can encourage multiple participants to provide data respectively, so as to solve the problems of data island and effective cooperation. Data federation model can achieve a win-win situationunder protecting privacy and security of participants, this is quite different from the current global data updating mode, including blockchain.Carrying out research on supply chain financing from the perspective of data federation can make supply chain financingreal-time, transparent and traceable,

also it promote real-world scenario application ofsupply chain financing.

The practice and theoretical research of supply chain financing can be summarized as evolving from financial orientation, supply chain orientation to network platform orientation and data orientation[1].To financial orientation type, the promoters of supply chain financing are banks and other financial institutions. Supply chain enterprises put forward loan demand to financial institutions based on their financial resources in the supply chain.Relevant scholars have proposed various financial services such as accounts receivable or accounts payable based on factoring and bills[2], inventory or movable property based on pledge[3], prepayment based on warehouse[4]. To supply chain orientation type,supply chain members mainly rely on the financial services of core enterprises to carry out financial services. Core enterprises are the promoters of this pattern, which also leads to the important impact on this mode once the core enterprises have financial problems. Zhao,etc proposed industrial supply chain financing, which provides comprehensive financial services to suppliers or customers based on the supply chain system[5].Song proposed the strategy of core enterprises providing guarantee to financial institutions[6], Hobergproposed the strategy of recommending strategic suppliers and customers[7], etc.The promoter of network platform oriented supply chain financing is an independent third party separated from industry and financial institutions. Its credit model does not pay attention to the credit of a single enterprise, role of cooperation status among supply chain participants in financing services is emphasized[8].Data oriented supply chain financingis no longer based on business network, but integrate digital information to promote financial services.It makes financial services more efficient and effective, shows a strong driving force in openness, balance and fairness[9], it has become the latest trend in the development of supply chain financing which forms digital supply chain financing and changes the operation mode of traditional supply chain financing.

Digital technology promotes the efficiency and benefit of financial services in the supply chain, and also it promotes the smooth flow of funds among the stakeholders in the supply chain. Carrying out financial service innovation based on digitization,it could get the digital feature description of enterprise credit, portrait and habits, so as to make effective decisions on enterprise financial needs.The data-oriented supply chain financial model requires supply chain enterprises to submit all their own data to upstream, downstream enterprises and financial institutions. This model lacks privacy protection and security mechanism, and the data provision process, rights and responsibilities are not clear enough. In addition, it may make the data information between supply chain enterprises and enterprises, between supply chain enterprises and financial institutions unable to confirm and reflect each other, thus it may not ensure the authenticity of trade[10]. In 2018, scholars in the fields of machine learning and artificial intelligence proposed the data federated learning model[11]. The main feature of federated learning is that in the process of distributed data training, the data of all parties are kept locally without divulging privacy or violating laws and regulations, so as to solve the problems of data privacy security and island. Relevant research results such as classification, clustering and regression based on federal learning have been successively published in high impact conferences and journals such as AAAI, ICML,IEEE, ACMtransactions journals[12,13,14]

The latest research results show thatfederal learning can achieve good application results in the financial field[15,16]. Firstly, federal learning can solve the problem of judgingaccuracy of financial requirements. For the financial needs of supply chain enterprises, judging and implementing financial decisions only from the data of financial institutions may lead to insufficient sample size. In addition, the sample characteristics may not be well distinguished in the existing data, and the sample distribution may be irregular.Usingfederated learning can solve this problem, it constructs a data learning model for repeated screening and data resampling, combines the data of all parties for targeted small sample modeling, so as to realize real-time data synchronization and ensure the accuracy of judgment and decision-making[17]. Secondly,

federated learning can realize multi-source data fusion. The data sources of supply chain enterprises are extremely rich, involving quantitative data such as transactions, logistics and production, as well as non-qualitative information such as contracts, orders and industry and commerce. The use of horizontal, vertical and transfer data federation can maximize the combination of data, greatly enrich the feature system and improve the effectiveness of the model[18]. Thirdly, federal learning can improve the effect of financial risk control. Intelligent risk control based on federated learning is conducive to promote the application of AI technology based on data security joint modeling, and improving the risk control ability of such industries. Federal learning has realized that it can participate in all links of the risk control process, including anti-fraud, preliminary screening of white list, pre credit, loan early warning, etc. According to the needs of business enterprises and institutions, multi-dimensional cooperation can be carried out. Through the legal compliance of the multi-dimensional federal data modeling, the effect of the risk control model can be significantly improved, and due to the increase and enrichment of data sample size, the ability of risk control is further enhanced[19].These three advantages make federal learning have a good prospect in supply chain financing to the enterprise.

Theresearch of supply chain financing has become ahot field. The current relevant research has the following shortcomings: (1) a supply chain financing trusted service model for data dispersion is still lacking. Based on the needs of security and privacy, the supply chain financing service model urgently needs to make a breakthrough from the theoretical level to highlight the problem of trust and coordination of supply chain financial data under data dispersion, rather than enterprises providing all their data to financial institutions. The data federation trust model can be used as a good solution to this problem. (2) Research on the internal mechanism of data technology model of supply chain financing service is not enough. At present, the internal mechanism of supply chain financial data has not been systematically studied. How to discover, transmit, apply and manage decentralized data in supply chain financing mode needs to be deeply excavated. (3) Research on data rights and responsibilities in supply chain financing risk is few. The data responsibility, power, process and standardization of supply chain financing entities are not clear enough, which may lead to data leakage risk or confusion in practical scenarios.

Tobacco supply chain refers to the collection of relevant stakeholders around the production and sales of products.It is a strategic alliance from raw and auxiliary material suppliers and equipment suppliers to industrial enterprises, transportation links, commercial enterprises, retailers, consumers, departments and personnel, etc.From the perspective of the whole supply chain, tobacco enterprises are connected with industrial enterprises and retail terminals.It is the core of the whole supply chain, the financial service of the tobacco enterprisescan maintain the stability of the supply chain, realize service value creation and service efficiency. In addition, it can reduce the production risk of the upstream and downstream.

In this paper, we mainly build a digital supply chain financing service model based on data federation. The scheme is based on digital technology to carry out financial services in the overall supply chain, involving many subjects, advocating digital trust, high efficiency, traceability and high wisdom of supply chain financing behavior. Taking tobacco supply chain as an example, multiple participants in the chaincombine data to establish a virtual common model and carry out financial decisions,so as to optimize capital flow in supply chain financing andreducedecision-making risk of financial institutions.

MODEL

Supply chain financing based on data federation is firstly reflected in the data decentralized learning, which makes the financial behavior of supply chain enterprises must reflect relevance and digitization. For supply chain enterprises, supply chain financing behavior data includes accounts receivable and payable, evidence of supply chain financial behavior, warehouse documents, purchase orders, insurance policies, shipping documents, etc. Fortunately, with the construction

of SME data platform, the acquisition of these data is no longer complex, after data acquisition, it will be encrypted and integrated into the federated model. For financial institutions, the first step is to extract the historical financial loan or financing performance data of enterprises that need financial services, then encrypt the historical data as attribute features and conduct federal learning, it is always training with the encrypted data in supply chain enterprises, highlighting the cooperative learning under the financial security privacy of the supply chain based on digital technology, and finally form a learning result. The result can be used as a decision judgment on the financial demand behavior of users.The process is not only relying on the financial institutions but also the enterprises for the risk minimization. The proposed data federation model ofsupply chain financing is shown in Figure 1 based on the data of two sides of financial institutions and enterprises.

The financial data of supply chain enterprises and the historical data of financial institutions have been sufficiently supplemented after federal learning, which is essentially different from the traditional method based on enterpriseapplication and single decision-making of financial institutions. With the updating of the amount of data, the effect of federal model will be closer to the actual situation, this will help financial institutions to make reasonable decisions on supply chain enterprises and avoid false transactions, lack of qualification and so on. In the whole federal learning process, the data has not left the local supply chain enterprises. The training data is encrypted characteristic data, which can also ensure the data security provided by the participants and solve the problem of privacy and confidentiality.Through the construction of data federation model on supply chain financing, the data does not leave the local server, and its integration effect is equivalent to unifying all data. Considering the sensitivity of each data party to data privacy, the data federation effectively ensures the data security through encryption. It can also be seen from the model in Figure 1, the status of each participant is equal. They jointly establish the federal model and obtain corresponding benefits.Through the study of three kinds of federal models, we can realize the link of decentralized data, which has a quantitative index basis for financial institutions to investigate enterprise qualification and financing limit. Supply chain enterprises can obtain the due financing scale to a greater extent, financial blacklist enterprises cannot obtain loans by forging trade information, and the core competitiveness of credit institutions has been strengthened.

METHODS

According to the different data characteristics of supply chain enterprises, three kinds of learning methods of federated learning can be used for data federation. It could be dividedas horizontal Federation, vertical Federation and Transfer Federation.

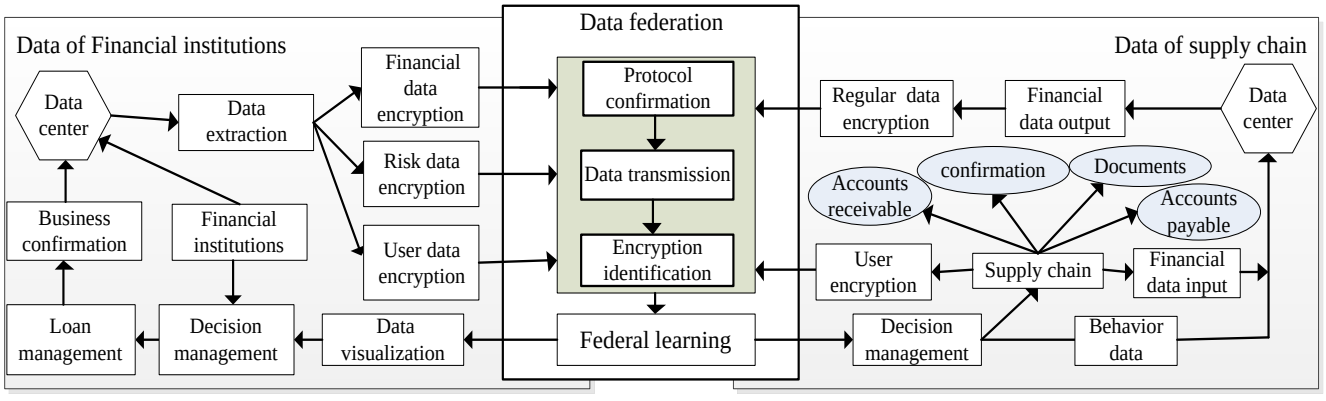

Figure 1 Supply chain financing with data federation model

Horizontal Federation is mainly used when the feature data are similar but the label users are different. The feature of the two types of data are similar,

but the objectives may be different. We only need to segment the part with the same feature data and then conduct federation learning. For example, for two downstream supply chain enterprises, they may come from different regions and have no intersection with each other, but their business attributes are similar, so they can use these business data training to build a horizontal federation model to identify such business enterprises.

Vertical Federation is mainly for federation learning based on different characteristics of the same user. It is the main type of supply chain financing with data federation. It aims at the data integration of a single supply chain enterprise under different scenarios and different servers, which is manifested in federation training based on different characteristics of the same user. For example, the transaction information between a supply chain enterprise and a core enterprise is saved in the core enterprise, and the historical financial information with the bank is saved in the bank server. The data saved in the core enterprise may be acted as supply chain operation information such as waybill, transaction amount and warehouse bill. The data retained in the bank is the revenue and expenditure behavior, credit rating of the enterprise and the bank, and there is less feature intersection between the two sides, thevertical federation model trains the data with the above different characteristics for decision-making.

Transfer Federation is mainly for training and learning when there is no intersection between users and features. It is for data integration without users and with different servers. It is manifested in introducing a mature migration training model into the training scenario or introducing a unilateral training model into the other side to adapt to the situation of few bilateral data users. For example, U.S. banks keep their relevant supply chain financial customers and Chinese banks keep their corresponding supply chain financial customers. There is less intersection between their characteristics and users. A bilateral data oriented transfer model is constructed to meet the customer demand identification in the two scenarios.

Fig.2 is the presentations of above three kinds of data federationin the order described above, A and B represent the enterprises or banks with data features. $x_i(i=1,\ldots,m)$,$y_i(j=1,\ldots,n)$ are the characters of A and B, M_H, M_V are the horizontalfederation and vertical federation, M could be known as a transfer model based on horizontal or vertical federation M_A,M_B. Table 1 shows the detail information of these three modes in the implementation of supply chain financing.

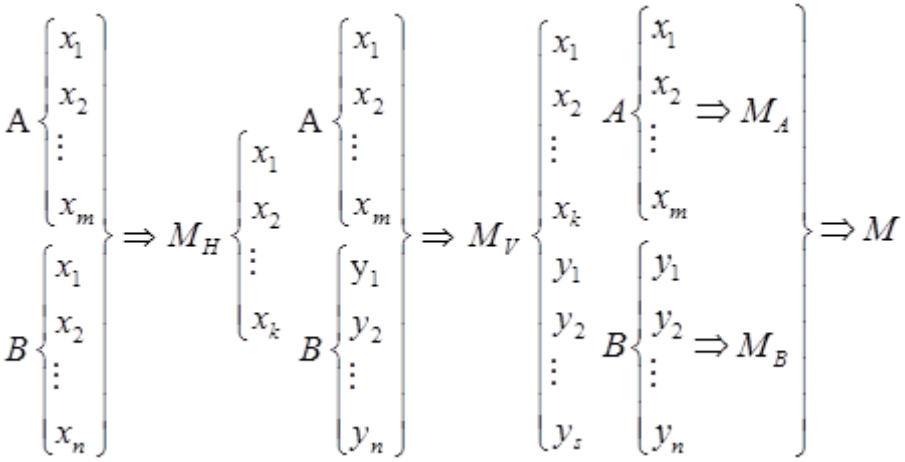

Figure 2 Three kinds of data federation

Table 1
Three Methods of Data Federation in Supply Chain Financing

Methods	Data Type	Data Sources	Federal learning content	Output
Horizontal Federation	Accounts receivable, credit, documents, bills	Supply chain enterprise	Federate learning of financial documents, bills and vouchers of each supply chain enterprise	Features
Vertical Federation	Financial demand, output data by horizontal federal, financial institution data	Supply chain enterprise,financial institution	Federate learning of output results byhorizontal federation,financial institutions,and financial demand by enterprises	Financial decision
Transfer Federation	Financial demand and financial institution data	Supply chain enterprise,financial institution	Transfer the mature training model or transfer the unilateral model to the other side for federal learning	Financial decision

Data Analysis

Statistical analysis was conducted with survey data. Theinvestigativeregion contains clusters of SMEsin manufacturing, including many enterprises in tobacco supply chain.Some companies and financial institutions we surveyed have implemented data federation strategy. The overall summary data of the companies and banks interviewed by the questionnaire are shown in Table 2.It can be seen from the last column that at present, enterprises and banks do not fully understand the financial services based on data federation. Core enterprises and large banks are more sensitive to this new technology, and a considerable proportion of users have begun to implement this strategy.

We will evaluate and analyze the overall supply chain financial risk strategy that has not implemented and implemented the data federation strategy. Firstly, we select the key factors that meet the characteristics of the supply chain, including five indicators: supply chain loan balance, cumulative loans receivable, number of loan projects, number of overdue loans, number of enterprise bankruptcies, etc.We select the default rateof enterprises as the dependent variable and implement multiple regressions as the calculation model, the parameters are estimated with nonlinear least square method.The calculation model of the survey data is established as:

$$\hat{y} = \beta_0 + \beta_1 x_1 + \beta_2 x_2 + \beta_3 x_3 + \beta_4 x_4 + \beta_5 x_5 + \varepsilon \quad (1)$$

We analyzed the significance of each parameter respectively. The significance analysis of parameter pointed out that which featuresmay be the key factor affecting enterprise performing loans, and we also investigated the comparison of key indicators before and after the implementation of data federation strategy based on F-test and t-test.

Table 2
Features and Measured Variables with Supply Chain Financing

Variables	Type	Number	Percentage	Proportion with data federation
Enterprise	Manufacturing company	102	42.8%	32.2%
	Distribution company	56	23.5%	23.1%
	Logistics company	64	26.9%	42.3%
	Core company	16	6.8%	56.8%
Bank	Small commercial banks	52	49.0%	11.7%
	Medium-sized joint-stock	36	34.1%	23.6%
	bankslarge banks	18	16.9%	52.9%

RESULTS

According to our questionnaire analysis, after the implementation of data federation, the average satisfaction of supply chain enterprises has increased by 12.5% compared with the previous years, and the financing needs of enterprises can be better and properly met. According to the survey data of the bank, after the implementation

of data federation, the overall risk control has been effectively controlled. In particular, the audit cost in the initial stage has been reduced by 23.5%. Through the preliminary audit, the blacklist and impossible loan customers have been screened out, and the financial institutions have further approached the supply chain transaction scenario. We conducted multiple regression and hypothesis test on the two groups of data before and after data federation. The relevant experimental results are shown in Table 3. It can be seen from table 3 that the average default rate of enterprises after the implementation of data federation is 3.82%, while the data of the control group without data federation is 4.73%, it is indicating that the supply chain financing strategy of data federation has achieved good risk control. In addition, we conducted significance analysis on the above fivefeatures respectively. Firstly, we tested whether the relationship between the dependent variable of enterprise default rate and the five independent variables was significant, that is, the overall significance test, set the significance level parameter to 0.1, and the p-values calculated by using the F test were 7.29e-2 and 1.04e-4, both of which were less than the significance level parameter, This means that the relationship between dependent variables and independent variables is significant in general. Although it is generally significant, it does not mean that there is a significant relationship between various variables. We test the significance of each regression coefficient. t-test is used in this stage. From the results in Table 3, it can be seen that the regression parameters of cumulative loans receivable and number of enterprise bankruptcies after the implementation of data federation are less than those before the implementation of data federation, This also shows that the relationship between these two items and dependent variables is closer after the implementation of data federation, and the quantitative control analysis of loans receivable and number of enterprise bankruptcies can be carried out after data federation, which also verifies the advantages of data federation.

Our survey also investigated the difficulties of enterprises implementing the supply chain under the data federation. For upstream and downstream enterprises, the reluctance of core enterprises to provide confirmation of rights for accounts receivable financing, order financing or prepayment financing are the most important problem, accounting for 85.5%. The supply chain business risk of upstream and downstream enterprises will affect the core enterprises, so the core enterprises are unwilling to carry out this business option, which is the main dilemma of the core enterprises, accounting for 92.3%. Strengthen the active docking of banks, customize the supply chain financial services according to the actual situation of the supply chain; Promote insurance companies to explore and innovate loan guarantee insurance required by supply chain financing, and resolve guarantee problems in the form of risk sharing; Establish a cross regional cooperation mechanism for banking institutions to effectively serve the needs of upstream and downstream to remote small and micro enterprises; the above three options have been chosen by each enterprise as suggestions for further improving the supply chain financial services.

Table 3
Statistical Results Before and After the Implementation of Data Federation Strategy

Stage	R^2	AIC	BIC	y(average)	F	Significance F	Coefficients>0
Supply Chain Financing without Data Federation	0.919	48.91	50.09	0.0473	6.788	0.0729	0.2886(x_2) 0.032(x_3) 0.4057(x_5)
Supply Chain Financing with Data Federation	0.995	12.35	14.17	0.0382	162.8	1.04e-4	0.0039(x_1) 0.0061(x_2) 0.0016(x_5)

APPLICATION

Tobacco production enterprise[20,21] is the core enterprise in the supply chain. It gathers all data, including all sellers, upstream and downstream logistics and transaction data. Financial

institutions can carry out financial services through cooperation with core production enterprises, mainly in the following three aspects:

The first is the loan problem. Assuming that a supplier of a core tobacco enterprise needs bank lending to maintain the liquidity of its funds, the bank can query the supplier's qualification, historical lending information, accounts receivable and payable, inventory and other information according to the results of data federation, so as to accurately allocate certain funds according to the lending requirements, which is different from that based on guarantee. In traditional ways, it is more about assets and people's credit, rather than trust in data.

The second is process optimization. In the overall process of tobacco supply chain, tobacco production and sales are the mainstream process. Under the framework of this core process, there are many specific cross organizational business processes. Many original processes are designed by various economic entities from their own point of view. They are optimal in a local scope, but not necessarily at the supply chain level. Therefore, it is necessary to re-examine the business process of tobacco supply chain from the perspective of supply chain. After data federation, all kinds of data are integrated together, which can better improve and optimize the efficiency of the supply chain.

The last one is risk control. For financial institutions, the business status of enterprises can be analyzed and controlled in real time after data federation. Once the enterprise may have risk, financial institutions and core tobaccoenterprises can inform the risk at the first time. In addition, the addition of new supplier enterprises may damage the original supply chain structure, which can also provide early risk early warning for the original members.Also, it includes behavior scene judgment. It includes effectively identifying the description and network status of enterprises in the supply chain structure, highlighting the network status and business development identification built by borrowers, upstream and downstream enterprises.

Among them, the data federation model solves the learning problem of decentralized data. The tobacco supply chain highlights the tight supply chain data type of core enterprises, which makes the data relatively easy to obtain, also it can provide a better foundation for financial services based on data federation.

MEASURE

The effective implementation of supply chain financing based on data federation needs the active cooperation of external policy environment.We put forward four development measures.Firstly it should speed up the policy guarantee for the landing of supply chain financing. As supply chain financing involves multiple departments within financial institutions, it is affected by the data capacity of financial institutions, data needs to be coordinated. Therefore, it is necessary to speed up the construction of enterprise data center, speed up the construction of data capacity of financial system, and speed up the construction of data flow cooperation capacity;the second one is risk management policies for supply chain financing must be introduced. The risk of supply chain financing looks like a financial problem, but in essence it is a supply chain economic problem. Although the risk of supply chain financing based on data federation has been reduced, it also needs the joint action of policy environment and other digital technologies to control the risk points and risk sources on each node of supply chain financing. Banks are the main implementers of data federation technology. They should jump out of supply chain financing to examine the role of supply chain in order to activate the liquidity of funds in the overall supply chain;the third measure is to develop the proportion of credit financing of supply chain enterprises vigorously. Commercial banks should gradually change the habitual practice of relying only on the core enterprises of the supply chain to extend credit to other enterprises, pay more attention to the quality evaluation of individual financing subjects, especially the development ability of the enterprisesand the data federation will convert the credit data of supply chain enterprises, which provides a strong implementation basis for the financial service mode based on credit

financing;the last one is implementing the differentiation policyfor each member of the supply chain. Core enterprises play a central role in the upstream and downstream of the supply chain enterprises. In fact, core enterprises must play an important dominant role in the supply chain financial system. Some products of supply chain financing can be established only based on the credit transactions of core enterprises, such as receivables bill financing. At this time, the right of core enterprises is required. To a certain extent, core enterprises have no obligation to issue legal documents in this regard to financial institutions. However, the operation mode of data federation emphasizes the effective cooperation of data. Although this cooperation is secure and encrypted, core enterprises may be reluctant to implement this technological innovation for some reasons. Financial institutions should give appropriate preferential financial policies and implement different interest rate policies for core enterprises undertaking credit guarantee in the supply chain, Encouraging core enterprises to take the initiative for fulfilling their responsibilities such as right confirmation and guarantee.

Study Limitations and Future Work

The supply chain financing model based on data federation activates the data in the supply chain. Data owners will be encouraged to join the data federation model, obtain their own value and reduce financing risk.It can have good application in core enterprise oriented integrated supply like tobacco supply chain. However, the sample size of our statistical survey is not enough. Upstream and downstream enterprises may have business risks, and their supply chain business risk will have an adverse impact on core enterprises. In addition, the federal learning standard of supply chain financing has not been formulated, the policies, measures, laws and regulations of financial data federation are not perfect, enterprises are not fully familiar with data federation, does federal learning have a good effect under more data noise? These problems need to be solved one by one in the future, so as to put the supply chain financing based on data federationtechnology intouse as soon as possible.

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Author Declaration

This research is not funded by any organization related to tobacco production.

Conflicts of Interest Disclosure Statement

The authors declare no conflict of interest in the authorship or publication of this work.

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