

Article

Research on the Effectiveness of Deep Learning—Based Agency Cost Suppression Strategy: A Case Study of State—Owned Enterprises in Mainland China

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Abstract: The mixed ownership reform aims to improve the property rights structure of the state—owned enterprises (SOEs) and reduce agency costs, and the current mixed reform strategies mainly include equity blending by introducing external non—state capital, executive assignments, and employee stock ownership. In this paper, 953 valid data of A—shares listed in Shanghai and Shenzhen from 2008 to 2020 are used as samples to construct the indicators of mixed reform strategy by the literature statistics method. After obtaining multiple impact indicators, the regression impact model of corporate agency cost suppression strategy is constructed by MATLAB software using a machine learning algorithm. On this basis, the performance of multiple machine learning algorithms is compared, and it is found that the integrated optimization—based bag—boosting model is used to study the effect of hybrid reform strategy to reduce the agency costs of SOEs, and the proportional setting of indicators when the effect is optimal is also explored. Finally, the laws of different influencing factors on the agency costs of enterprises are explored separately by the eigenvalue method. The results of the study show that the proportion of shareholding of the first largest non—state shareholder is sin—functional with the agency costs of SOEs when non—state majority shareholders are introduced into SOEs' equity mix, and the agency costs tend to decrease after SOEs become privately held enterprises. The greater the number and proportion of supervisors appointed by non—state shareholders, the greater the supervisory restraint effect on SOE managers and the better the effect of suppressing agency costs. The participation of non—state—owned shareholders in the company's business decisions by appointed executives and the special resource advantages of SOEs intensify the occurrence of the self—interest of appointed executives and the increase of agency costs of SOEs. The implementation of an employee stock ownership plan plays the role of employee supervision and restraint on SOE managers, which reduces the agency costs of SOEs. Based on this, it can provide support for the government to improve the hybrid reform policy and promote the process layer by layer, and also provide theoretical reference for SOEs to deepen the equity mix, incentivize employee shareholding, and empower non—state shareholders to govern and thus reduce agency costs.



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Keywords: machine learning; mixed ownership reform; equity mixing; executive assignment; employee stock ownership; agency cost

1. Introduction

The ultimate goal of modern listed companies is to maximize enterprise value, but shareholders are often unable to personally manage the daily business activities of enterprises due to their own lack of relevant professional knowledge or having no free time, so they need to entrust professionals to manage the enterprises, and the relationship between shareholders and managers arises from the commission and agency. The shareholders entrust the management personnel to manage the enterprise on their behalf, which will inevitably generate certain agency costs, mainly in two aspects. On the one hand, the shareholders have to supervise the behavior of the management personnel or have to

motivate the management personnel to make beneficial actions for the enterprise, and on the other hand, the unavoidable costs incurred by the external professional management personnel to manage the enterprise. The existence of agency costs can greatly affect the performance of business activities, especially financial performance, so it is meaningful to study agency costs to improve the financial performance of the company.

State-owned enterprises, especially wholly state-owned enterprises (SOEs), have high agency costs due to the “lack of owner” problem of universal property rights [1], which has led to several rounds of SOE reforms [2]. The 2013 mixed ownership reform (hereinafter referred to as mixed reform) aims to improve the property rights structure of SOEs by introducing non-public capital, playing the role of non-state shareholders to monitor and discipline SOE executives, and reducing agency costs [3]. At present, China is in a period of deepening structural reform of SOEs, with hybridization being an important breakthrough. Exploring the effect of the hybridization strategy to reduce agency costs of SOEs and the proportional setting of strategy indicators when the effect is optimal can further test the effectiveness of the current hybridization policy and provide a theoretical basis for the next step of deepening the hybridization of SOEs. Currently, hybrid reform mainly adopts three strategies of equity mix [4], executive assignment [5], and employee stock ownership plan implementation [6,7].

There are controversies in academic circles about the necessity of equity mix in SOEs, and scholars in support of the theory, represented by Weiying Zhang, argue that SOE mix reduces policy burden and excessive indebtedness, can promote innovation [8,9], enhance the performance sensitivity of SOE executive compensation [10], strengthen the quality of accounting information [11], and improve their economic efficiency [12,13] while boosting the macroeconomic growth rate [14]. Opposition scholars, represented by Justin Yifu Lin, argue that SOE hybrid reform leads to more severe budgetary soft constraints, private interests due to control rights [15], the presence of state-owned shares or executive political affiliates exhibit wasteful resources, and excessive reduction in the proportion of state-owned shares is not conducive to improving corporate performance [16], which will eventually result in the loss of state-owned assets as the hybrid reform advances [17]. An important policy goal of SOE hybrid reform is to improve the ownership structure of SOEs and alleviate the agency problem of SOEs, and scholars have explored whether the SOE equity mix can reduce agency costs based on traditional econometric statistical methods. Cao Yue et al. [18] found that it is difficult for SOEs to improve the quality of internal control by only achieving equity diversity, and only when hybrid SOEs form certain equity checks and balances can non-state shareholders improve corporate governance [19], supervise and restrain management's cost-manipulation behavior for self-interest motives [20], inhibit agency conflicts [21], and thus reduce agency costs.

Scholars on SOEs' hybrid reform strategies have shifted from the equity mix perspective to the executive appointment dimension, and Cai Guilong et al. [10] found that it is difficult for non-state shareholders to form checks and balances on SOEs' hands due to their low shareholding in SOEs under the logic of equity and control parity. Given this, Zhu Jigao [22] proposed that equity and control as two independent tools can be used separately to solve the current problem of non-state capital in SOEs without the right (control) to change the decision-making of the state capital. The involvement of non-state shareholders in the senior governance of SOEs by appointing executives is consistent with the logic of non-reciprocal configuration of control and ownership [16], and the actual participation of non-state shareholders in the exercise of power in SOEs' business decisions can significantly improve the quality of internal control of SOEs, improve the quality of internal control of competitive SOEs and local SOEs, and effectively reduce the agency costs of SOEs [23]. Further, the effect of non-state shareholders in reducing SOE agency costs is more prominent when they have excess power to appoint executives relative to their equity [24].

At present, scholars at home and abroad have conducted less research from the perspective of employee stock ownership plans as a strategy for SOEs' mixed reform, and

there is a lack of research on SOEs' agency costs. As a breakthrough in hybrid reform, employee stock ownership plans should have a more positive effect in theory, but due to the insufficient incentive of employee stock ownership plans, it is difficult to improve the agency problem of SOEs by implementing employee stock ownership plans in hybrid reform [25]. It is necessary to conduct further research on the hybrid effect of employee stock ownership plans to support the optimization of employee stock ownership programs.

In summary, domestic and foreign scholars have conducted rich research on SOEs' hybrid reform based on traditional econometric statistical methods [26], but there is room for research. First, the privatization process of SOEs abroad was concentrated in the 1990s, and the differences in economic systems and privatization methods make it difficult to apply foreign experience to China, where SOE hybrid reform has entered a deepening phase, among which employee stock ownership plans are the most typical, and employee stock ownership plans in China, as an important system of SOE hybrid reform, differ significantly from foreign system design, and the system implementation effects are bound to be different. Secondly, there is controversy about the necessity of mixed reform, and there is an urgent need to demonstrate the effect of mixed reform strategies. The investigation of the optimal ratio of mixed reform strategy indicators can effectively address the concerns raised by scholars who oppose mixed reform. Once again, domestic and foreign scholars have not paid enough attention to employee stock ownership as a mixed reform strategy for SOEs, and fewer scholars have compared the differences in the effect of different mixed reform strategies in reducing agency costs of SOEs. Finally, the current literature explores the economic consequences of mixed reform based on traditional econometric and statistical methods, and the research methods need to be enriched and the accuracy needs to be improved.

With the development of emerging technologies, machine learning has gained much attention for its superior performance in traditional industries, especially in data processing [27,28]. Based on the differences in domestic and foreign institutional systems, the difficulty of learning from foreign experiences, the controversies about the necessity of mixed reform of SOEs in China, and the lack of attention to employee stock ownership as a mixed reform strategy, this paper innovatively constructs a model based on machine learning algorithms to explore the effects of mixed reform strategies on agency costs of SOEs, and identifies the optimal ratio settings of mixed reform strategy indicators while testing the effectiveness of policies. In this paper, we investigate the impact of the hybrid reform strategy on the agency costs of SOEs from three dimensions: equity mix, executive assignment, and employee shareholding, among which, equity mix is based on three perspectives: breadth, depth, and checks and balances of equity mix and the indicator design are comprehensive and rich. In addition, compared with the traditional econometric statistical methods, this paper combines previous studies to compare and analyze the regression performance of various algorithms. The main ones are the bag-boosting algorithm, the long and short-term memory neural network algorithm, and ridge regression [29]. Among them, the long and short-term memory neural network algorithm and the ridge regression algorithm have been researched by previous authors, and the application of the bag-boosting algorithm on the agency costs of SOEs is the focus of this paper. This method can obtain the proportional settings of different indicators when the effect of reducing SOE agency costs is optimal, and it can verify the effectiveness of current hybrid reform policies while analyzing the next hybrid reform directions and strategies for policymakers and SOE managers concerning the current situation of hybrid reform.

Domestic and foreign scholars have studied agency costs from a variety of perspectives. Some domestic scholars use statistical methods to measure agency costs from the perspective of the internal contract system and find that agency costs largely affect the efficiency of enterprises; some study the relationship between family business management and agency costs; some study directly from the root cause of agency costs, the agency problem; other scholars study the relationship between equity concentration and checks and balances and agency costs and find that in enterprises of different nature, the relation-

ship between the two is different. In addition to the relationship between the quality of financial reporting and the two types of agency costs, agency costs also vary depending on the nature of the enterprise. Improving the quality of internal control and moderating debt can also help to reduce agency costs between management and shareholders. Some foreign scholars also believe that debt affects agency costs, in addition to the innovative and ownership structure of the enterprise, the separation of powers also affects agency costs. The purpose of this paper is to explore the influence model of multiple influencing factors on enterprise agency costs through an advanced machine learning algorithm and to obtain the influence law of different influencing factors on enterprise agency costs. In other words, this paper focuses more on the analysis of empirical research, aiming to explore the impact of agency costs on enterprises through empirical analysis, so as to provide reference and new solution ideas for the government to formulate policies and enterprises to plan development strategies. Therefore, this paper focuses more on the construction of the algorithm and the measurement of indicators.

2. Research Framework and Algorithm Design

2.1. Research Framework

This paper explores the effects of three SOE hybrid strategies on agency costs based on various machine learning algorithms, among which the model constructed based on the bag–boosting algorithm can tap the ratio setting when the effect of strategy indicators is optimal, which is one of the focuses of this research paper. The research process of this paper can be extracted into four parts: data preprocessing, constructing a model and optimizing it, model prediction, and conclusion. The research framework is shown in Figure 1.

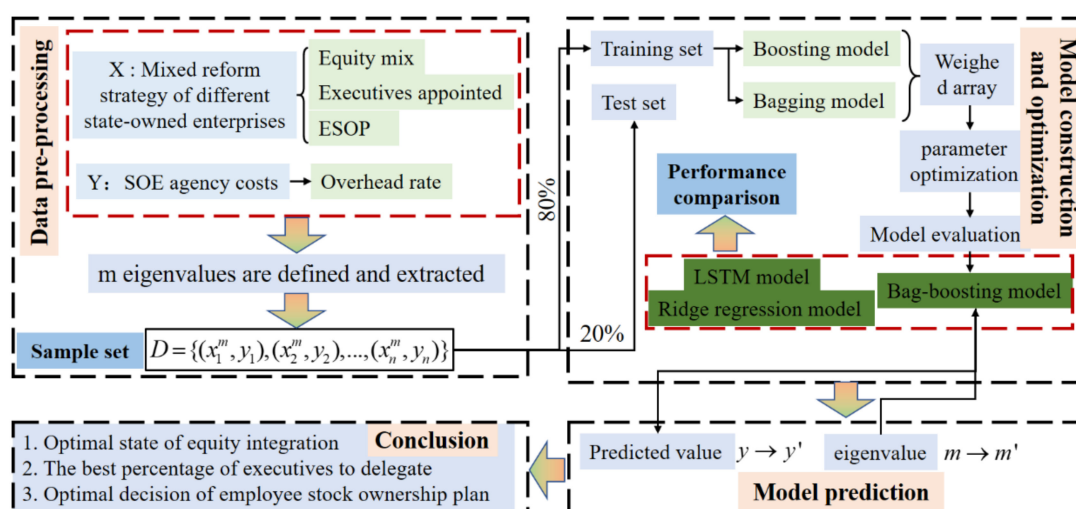


Figure 1. Research framework diagram.

Data pre–processing: The data were crawled and downloaded from the websites of the Shenzhen Stock Exchange, Shanghai Stock Exchange, Baidu, and Juchao Information, as well as the Wind Financial Research Database and CASPAR Database for SOE mixed reform strategies and enterprise–related financial data. Among them, there are 3 dimensions of mixed reform strategies, counting 16 feature values (m –values in Figure 1).

The model was constructed and optimized. A total of 80% of the data in sample set D are used for training and 20% for prediction. In the training process, the weighted combination of the boosting and bagging training model is used to obtain the bag–boosting model by setting the model–seeking conditions. The performance of the bag–boosting model is also evaluated by comparing it with the prediction effects of Ridge Regression and LSTM.

Model prediction: Concerning the maximum and minimum values of m in the sample set D , the changes in the agency costs of SOEs are predicted when a certain eigenvalue

changes in a certain range in the form of random numbers, and the proportion setting when the effect of each eigenvalue is optimal is explored.

Conclusion: The prediction results are analyzed to provide managerial suggestions for improving the current stage of the hybrid system and reducing the agency costs of SOEs.

2.2. Algorithm Design

Bag–boosting is a weighted combined model of boosting and bagging training models. Among them, boosting is a method of generating sequences serially with strong dependencies between individual learners, and bagging is a method of generating sequences in parallel without strong dependencies between individual learners. The combined model notation is defined in Table 1 below.

Table 1. Symbols and definitions in combinatorial models.

Symbol	Definition
D	Sample set of X –value and Y –value combinations
x	Vector values of X
H	Hypothesis set
$\{\dots\}$	Set
$\mathcal{D}$	Probability distribution
$ D $	D number of elements in the sample set
$P(\cdot)$	Probability quality function
$P(\cdot \cdot)$	Conditional probability mass function
$E_{\sim \mathcal{D}}[f(\cdot)]$	Mathematical expectation of the function $f(\cdot)$ for $\cdot$ under the distribution $\mathcal{D}$
$I(\cdot)$	Indicator function, $\cdot$ is true and false take the value of 1, 0, respectively
$\text{sign}(\cdot)$	Sign function, $\cdot < 0, = 0, > 0$ take the value of $-1, 0, 1$, respectively
T	Number of training rounds
ζ	Base learning algorithm
d	Number of decision tree node attributes
$H^{\text{ob}}(\cdot)$	Out–of–wrap prediction for samples

In the derivation of the formula for serially generated strong learners, the strong learners under strong dependencies among individual learners are derived by optimizing the exponential loss function. That is, the exponential loss function of Equation (2) is minimized by a linear combination of the basic learners, see Equation (1).

$$H(x) = \sum_{t=1}^T \alpha_t h_t(x) \quad (1)$$

$$l_{\text{exp}}(H|\mathcal{D}) = E_{x \sim \mathcal{D}} \left[e^{-f(x)H(x)} \right] \quad (2)$$

The first basic classifier h_1 is obtained based on the initial data; thereafter, h_t is generated iteratively, and when the basic classifier h_t is generated based on the distribution $\mathcal{D}_t$, this basic classifier weight α_t should be such that $\alpha_t h_t$ minimizes the exponential loss function, i.e.,

$$\begin{aligned}
 l_{\text{exp}}(\alpha_t h_t | \mathcal{D}_t) &= E_{(x \sim \mathcal{D}_t)} [e^{-f(x)\alpha_t h_t(x)}] \\
 &= E_{(x \sim \mathcal{D}_t)} [e^{-\alpha_t} I(f(x) = h_t(x)) + e^{\alpha_t} I(f(x) \neq h_t(x))] \\
 &= e^{-\alpha_t} P_{(x \sim \mathcal{D}_t)}(f(x) = h_t(x)) + e^{\alpha_t} P_{(x \sim \mathcal{D}_t)}(f(x) \neq h_t(x)) \\
 &= e^{-\alpha_t} (1 - \epsilon_t) + e^{\alpha_t} \epsilon_t
 \end{aligned} \quad (3)$$

where $\epsilon_t = P_{x \sim \mathcal{D}_t}(f(x) \neq h_t(x))$. Consider the derivative of the exponential loss function.

$$\frac{\partial l_{\text{exp}}(\alpha_t h_t | \mathcal{D}_t)}{\partial \alpha_t} = -e^{-\alpha_t} (1 - \epsilon_t) + e^{\alpha_t} \epsilon_t \quad (4)$$

Letting the above equation be zero yields the classifier weight update formula.

$$\alpha_t = \frac{1}{2} \ln \left(\frac{1 - \epsilon_t}{\epsilon_t} \right) \quad (5)$$

After obtaining H_{t-1} , the sample distribution will be adjusted so that the next round of the basic learner h_t corrects all the errors of H_{t-1} , minimizing $l_{\exp}(H_{t-1} + h_t | \mathcal{D})$ can be simplified by minimizing the following Equation (6).

$$\begin{aligned} l_{\exp}(H_{t-1} + h_t | \mathcal{D}) &= E_{x \sim \mathcal{D}_t} [e^{-f(x)(H_{t-1}(x) + h_t(x))}] \\ &= E_{x \sim \mathcal{D}_t} [e^{-f(x)H_{t-1}(x)} e^{-f(x)h_t(x)}] \end{aligned} \quad (6)$$

Let $f^2(x) = h_t^2(x) = 1$. The above equation can be approximated using the $e^{-f(x)h_t(x)}$ Taylor expansion as Equation (7).

$$\begin{aligned} l_{\exp}(H_{t-1} + h_t | \mathcal{D}) &\simeq E_{x \sim \mathcal{D}_t} [e^{-f(x)H_{t-1}(x)} (1 - f(x)h_t(x) + \frac{f^2(x)h_t^2(x)}{2})] \\ &= E_{x \sim \mathcal{D}_t} [e^{-f(x)H_{t-1}(x)} (1 - f(x)h_t(x) + \frac{1}{2})] \end{aligned} \quad (7)$$

Thus, the ideal basic learner is obtained.

$$\begin{aligned} h_t(x) &= \underbrace{\operatorname{argmin}_h}_{h} l_{\exp}(H_{t-1} + h | \mathcal{D}) \\ &= \underbrace{\operatorname{argmax}_h}_{h} E_{x \sim \mathcal{D}} [e^{-f(x)H_{t-1}(x)} f(x)h_t(x)] \\ &= \underbrace{\operatorname{argmax}_h}_{h} E_{x \sim \mathcal{D}} \left[\frac{e^{-f(x)H_{t-1}(x)}}{E_{x \sim \mathcal{D}} [e^{-f(x)H_{t-1}(x)}]} f(x)h_t(x) \right] \end{aligned} \quad (8)$$

where $E_{x \sim \mathcal{D}} [e^{-f(x)H_{t-1}(x)}]$ is a constant and let $\mathcal{D}_t$ denote a distribution.

$$\mathcal{D}_t(x) = \frac{\mathcal{D}(x)e^{-f(x)H_{t-1}(x)}}{E_{x \sim \mathcal{D}} [e^{-f(x)H_{t-1}(x)}]} \quad (9)$$

According to the definition of mathematical expectation, it is equivalent to the following definition.

$$h_t(x) = \underbrace{\operatorname{argmax}_h}_{h} E_{x \sim \mathcal{D}} [f(x)h(x)] \quad (10)$$

Since $f(x), h(x) \in \{-1, 1\}$, one can have the following definitions.

$$f(x)h(x) = 1 - 2I(f(x) \neq h_t(x)) \quad (11)$$

Then the ideal basic learner can be transformed into the following equation.

$$h_t(x) = \underbrace{\operatorname{argmax}_h}_{h} E_{x \sim \mathcal{D}} [I(f(x) \neq h_t(x))] \quad (12)$$

It follows that the ideal h_t will minimize the error function under the distribution $\mathcal{D}_t$. Therefore, the weak classifier will be trained based on the distribution $\mathcal{D}_t$ and the error against $\mathcal{D}_t$ should be less than 0.5. This is to some extent similar to the residual approximation idea. Considering the relationship between $\mathcal{D}_t$ and $\mathcal{D}_{t+1}$, the sample distribution update formula is obtained.

$$\begin{aligned} \mathcal{D}_{t+1}(x) &= \frac{\mathcal{D}(x)e^{-f(x)H_t(x)}}{E_{x \sim \mathcal{D}} [e^{-f(x)H_t(x)}]} \\ &= \mathcal{D}_t(x)e^{-f(x)\alpha_t h_t(x)} \frac{E_{x \sim \mathcal{D}} [e^{-f(x)H_{t-1}(x)}]}{E_{x \sim \mathcal{D}} [e^{-f(x)H_t(x)}]} \end{aligned} \quad (13)$$

Similarly, in the derivation of the formula for the parallel generative strong learner, the probability that a sample is always not collected in k samples is $\left(1 - \frac{1}{k}\right)^k$ when making a put–back sampling in a data set containing k samples, taking the limit to obtain.

$$\lim_{k \rightarrow \infty} \left(1 - \frac{1}{k}\right)^k = \frac{1}{e} \approx 0.368 \quad (14)$$

The above equation illustrates that about 63.2% of the samples in the initial training set appear in the sampling set, leaving 36.8% of the samples available as the validation set for out–of–bag estimation of the generalization performance. Let $\mathcal{D}_t$ denote the actual training sample set used by h_t and $H^{oob}(x)$ denote the out–of–bag estimation of sample x .

$$H^{oob}(x) = \underset{y \in \mathcal{Y}}{\operatorname{argmax}} \sum_{t=1}^T I(h_t(x) = y) I(x \notin \mathcal{D}_t) \quad (15)$$

The out–of–wrap estimate of the generalization error is given by the following equation.

$$\epsilon^{oob} = \frac{1}{|D|} \sum_{(x,y) \in D} I(H^{oob}(x) \neq y) \quad (16)$$

Based on the above model, a decision tree is introduced as the basic learner, while random attribute selection is introduced in the training process. The traditional decision tree selects an optimal attribute in the attribute set of the current node (assuming there are d attributes) when choosing the attributes for division, while the model in this paper selects a random subset containing k attributes in the attribute set of each node of the base decision tree, and then selects an optimal attribute from this subset for division, and here the parameter k controls the degree of randomness introduced. If $k = d$, the construction of the base decision tree is the same as the traditional decision tree. If $k = 1$, an attribute is randomly selected for division. In general, $k = \log_2 d$.

The basic learner diversity of the model in this paper comes not only from sample perturbations but also from attribute perturbations, which allows the generalization performance of the final integration to be further enhanced by the increase in the degree of variation among individual learners.

The basic learners generated under the weighted serial and parallel algorithms are given higher weights to the better–performing models to obtain the combined bag–boosting model, and the algorithm process is shown in Figure 2 below.

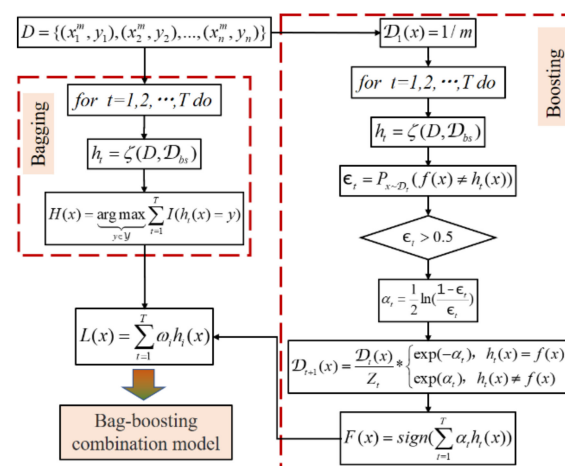


Figure 2. Bag–boosting model algorithm flow chart.

In the process of parallel generation of basic learners by the bagging algorithm, firstly, t ($t < m$) subsets are selected uniformly and with put–back from the training set of size n as

the new training set using the self-service sampling method. Secondly, t -tree models are trained using the regression algorithm. Finally, the summary model is obtained by averaging.

The boosting algorithm serially generates the basic learner process. First, it is assumed that the training data set has a uniform weight distribution, i.e., each training sample plays the same role in the learning of the basic classifier, and this assumption ensures that the basic classifier can be learned on the original data in step one. Second, the training sample distribution is adjusted according to the performance of the basic classifier, so that subsequent training focuses more on the training samples that the basic classifier does wrong, and the weight distribution α_t of the training data is updated to prepare for the next round. Next, the previous step is repeated at time $t = 1, 2, \dots, T$, and the basic classifier is learned repeatedly using the training dataset with weight α_t , and the classification error value e_t of the basic classifier on the weighted training dataset is calculated. Finally, the linear weighted combination of the T basic classifiers is implemented.

3. Data Processing and Index Measurement

3.1. Data Processing

In 2008, China implemented the shareholding reform, which enabled non-state capital to achieve universal participation in state-owned listed companies. After excluding data from the samples with missing financial, ST, PT, and main variables, there were 953 remaining. Of the listed SOEs, most of them are invested by different investment institutions. From the results of previous studies, it can be found that the average exit time of investment institutions in the process of investment is about 1 year. This means that there is a time lag for firms to obtain performance, which will also give a lag time for their agency costs. Therefore, given that the current latest sample data is 2021, with a one-year lag time, the final time interval chosen is 2008–2020. The reason for choosing SOEs as the research object in this paper is that the data on that part of SOEs are more complete in the current publicly available data on listed enterprises in mainland China. If privately listed enterprises are chosen as the research object, the number of enterprises meeting all indicators is small. In addition, the number of enterprises under each type is small, which would make the research results not generalizable. Although the research object of this paper is SOEs, this paper is mainly concerned with the empirical method of research. The purpose of this paper is to explore the use of nonlinear machine learning arithmetic to construct regression models of firms' agency costs. More attention is paid to the applicability of the empirical method rather than the data itself. In this paper, the data on company finance and employee stock ownership plan implementation are obtained from Wind Financial Research Database; the data on the equity mix of mixed reform of state-owned enterprises are mainly from the CAMAR database, annual reports disclosed by Shenzhen and Shanghai Stock Exchanges and websites such as Baidu and Tian-eye search; the data on executive assignments are mainly from CAMAR database, annual reports disclosed by Shenzhen and Shanghai Stock Exchanges and Juchao Information Database; the data on executive assignments are mainly obtained from CAMAR database, annual reports disclosed by Shenzhen and Shanghai stock exchanges and Juchao information database. To address the issue of the absence of descriptive statistics for sample data, this paper is concerned with the study of empirical analysis methods rather than the data itself. In this paper, a nonlinear machine learning approach is used to construct a regression model and use it for the prediction of unknown data. The advantage of this method is that only the original data need to be input into the model, and the model will automatically learn from the original data to obtain the implied patterns in the data, thus eliminating the need for human statistical analysis of the data. In addition, when the data is analyzed statistically by humans, personal subjective will is added to the statistical criteria, which makes the results not generalizable. Thus, the findings of the manuscript cannot be generalized more widely. Furthermore, the descriptive statistical analyses were all in preparation for the correlation analysis after the subsequent linear regression modeling

analysis, which was not performed in this paper, and, therefore, the descriptive statistical analyses were not significant for the analysis of the results.

3.2. Index Measurement

The process of selecting and constructing indicators is shown in Figure 3 below, and the whole process is divided into four steps: acquisition of data and construction of indicators for equity mix, acquisition of data and construction of indicators for executive assignments, acquisition of data and construction of indicators for employee stock ownership plan, and acquisition of data and construction of indicators for sample set D.

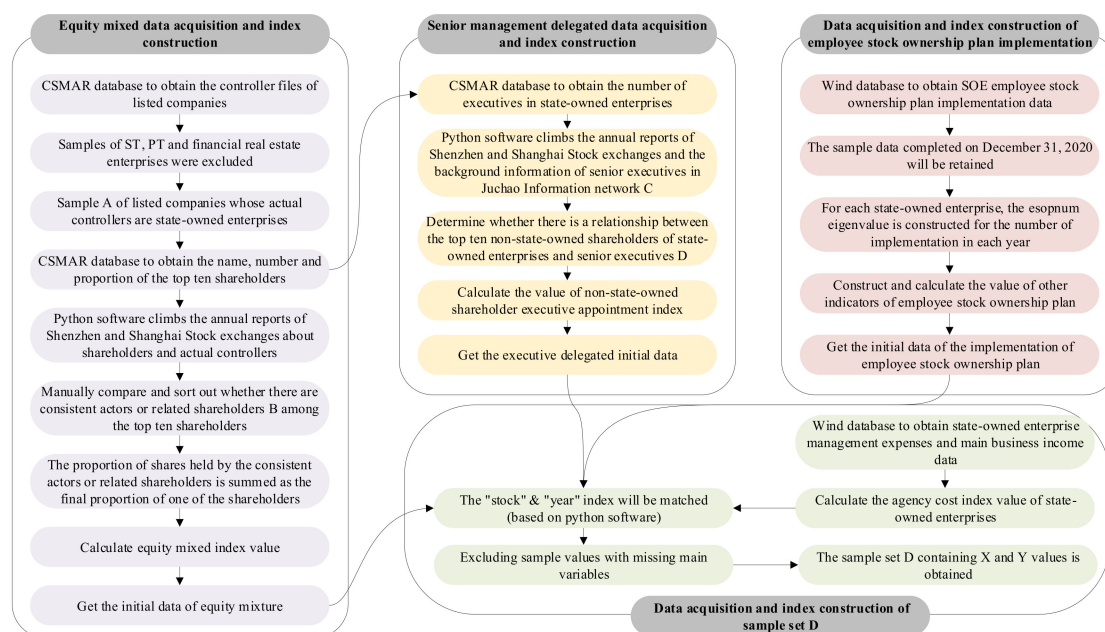


Figure 3. Selection of indicators and construction process.

Equity mixed data acquisition and index construction: Firstly, we downloaded the file of actual controllers of listed companies from the CSMAR database and excluded the samples of ST, PT, and financial real estate companies. Secondly, the sample of companies whose actual controllers are state-owned enterprises were screened out, i.e., the sample companies with label values of “1100”, “2000”, “2100”, and “2120” were retained. Then, we downloaded the top ten shareholders of the screened SOEs from the CSMAR database to obtain the shareholder names, shareholding numbers, and shareholding ratios. Then, we crawled the text of shareholders and actual controllers in the annual reports disclosed by the sample SOEs in Shenzhen and Shanghai stock exchanges based on Python, and manually compared and sorted out whether there were concerted actors or related shareholders among the top ten shareholders, and if there were, the shareholding ratio of both was summed up and used as the final shareholding ratio of one of the shareholders. Finally, the values of each indicator of the mixed equity of SOEs were calculated.

It is easy to find from previous studies [9–11] that the equity mix indicators are selected considering both the depth of mix (such as the shareholding ratio of the first largest non-state shareholder (shr1th), the shareholding ratio of all non-state shareholders among the top ten shareholders (shrt), and whether the first largest non-state shareholder is the controlling shareholder dummy variable (k1th)) and the breadth of mix and checks and balances (such as the type of shareholding among the top ten shareholders (catg) as well as equity checks and balances (ebal)). Here, the equity types cover four categories: state-owned shareholders, private shareholders (domestic non-state-owned corporate legal persons, domestic natural persons), foreign shareholders (foreign corporate legal persons, foreign natural persons), and others. If there is only one type of shareholder, the

value is 1. If there are two types of shareholders, the value is 2. And so on, the range of equity types is 1 to 4.

Executive appointment data acquisition and index construction: Firstly, based on the top ten shareholders document compiled in the first step, we downloaded the data of directors and supervisors of sample SOEs from the CSMAR database, including the number and names of directors and supervisors. Secondly, based on Python software, we crawled the content of the annual reports disclosed by the sample SOEs in Shenzhen and Shanghai stock exchanges regarding the information of senior executives, and used the information of senior executives in the Juchao information website as supplementary and auxiliary verification materials. Further, we determined whether there is a relationship between the executives of the sample SOEs and the top ten shareholders. The relationship mainly covers three cases: (1) The executives of the sample SOEs have worked in other enterprises held by the top ten shareholders. (2) The executives of the sample SOEs have worked in the affiliated enterprises of the other enterprises held by the top ten shareholders. (3) The executives of the sample SOEs have worked in another enterprise jointly owned by the top ten shareholders. Finally, the values of each indicator of SOEs' hybrid executive assignments were calculated.

From previous studies [22–24], it is known that executive assignment indicators are usually calculated using the presence of a dummy variable for the presence of directors appointed by non–state shareholders in the board of directors (ifad), the number of directors appointed by non–state shareholders among the top ten shareholders (adnum), the number of supervisors appointed by non–state shareholders among the top ten shareholders (asnum), the number of executives appointed by non–state shareholders among the top ten shareholders (aenum) The number of directors appointed by non–state shareholders among the top ten shareholders (adrat), the proportion of supervisors appointed by non–state shareholders among the top ten shareholders (asrat), the proportion of executives appointed by non–state shareholders among the top ten shareholders (aerat), and the total proportion of directors, supervisors and executives appointed by non–state shareholders among the top ten shareholders (adserat) are measured by eight indicators.

Employee stock ownership plan data acquisition and index construction: First, the data on the implementation of employee stock ownership plans implemented by sample SOEs up to 31 December 2020 were obtained from the Wind Financial Research Database. Based on the previous research results [8–10], the dummy variables of employee stock ownership plan implementation (esop) and the proportion of employee stock ownership plan implementation share capital and the total company share capital (imprat) indicators are constructed. In addition, this paper considers that the frequency of employee stock ownership plan implementation is an important factor affecting the number of employees holding company shares and the employees' rights to monitor and restrain the behavior of executives, so this paper innovatively adds the indicator of the number of times an employee stock ownership plan is implemented (esopnum) in a listed company within one year. The value of esopnum is 1 if a listed company implements it only once a year, and 2 if it implements it twice. And so on, the range of this indicator is 1–3.

Data acquisition and index construction for sample set D: First, the research results of Gong et al. showed [11] that the overhead rate of a firm is used as a proxy variable for agency costs, and the overhead rate $(G\&A) = \text{overhead} / \text{main business revenue}$. For this purpose, this paper obtained data on the overhead expenses and main business income of sample SOEs from the Wind Financial Research Database and calculated the overhead rate. Next, the data generated in the first three steps were matched with the overhead rate data based on Python software using “stock” and “year” as indexes. The sample values with missing main variables were removed while matching. Finally, the data set D containing the sample values of X and Y was aggregated. The 16 evaluation indicators selected in this paper are summarized from published data and the results of previous studies. For the issue of references of variable definitions, relevant references have been made in the previous index construction, and the same index has different descriptions in different literature. Therefore,

the definition of variables in this paper is a summary of the research results of several scholars, rather than a single citation of a certain piece of literature. Therefore, the references cited in this paper are placed in the explanatory description of the variables rather than listed in the table. After the index construction is completed, the specific variables of the final selected indexes in this paper are defined in Table 2.

Table 2. Variable definition table.

Symbol	Definition
<i>G&A</i>	Management expense ratio
<i>shr1th</i>	Shareholding ratio of the first largest non-state shareholder
<i>shrt</i>	Shareholding ratio of all non-state shareholders among the top ten shareholders
<i>k1th</i>	Whether the first non-state shareholder is the controlling shareholder dummy variable, yes takes the value of 1, otherwise takes 0
<i>catg</i>	Type of shareholding among the top ten shareholders
<i>ebal</i>	Shareholding checks and balances (proportion of non-state shareholders among top ten shareholders/proportion of state shareholders' shareholding)
<i>ifad</i>	Whether there are directors appointed by non-state-owned shareholders in the board of directors dummy variable, yes takes the value of 1, otherwise takes the value of 0
<i>adnum</i>	Number of directors appointed by non-state shareholders among the top ten shareholders
<i>asnum</i>	Number of supervisors appointed by non-state-owned shareholders among the top ten shareholders
<i>aenum</i>	Number of senior executives appointed by non-state shareholders among the top ten shareholders
<i>adrat</i>	Proportion of directors appointed by non-state-owned shareholders among the top ten shareholders
<i>asrat</i>	Proportion of supervisors appointed by non-state-owned shareholders among the top ten shareholders
<i>aerat</i>	Proportion of senior management appointed by non-state-owned shareholders among the top ten shareholders
<i>adserat</i>	Total proportion of directors and supervisors appointed by non-state-owned shareholders among the top ten shareholders
<i>esop</i>	Dummy variable for the implementation of employee stock ownership plan, if the value is 1, otherwise it is 0
<i>imprat</i>	Shareholding plan of employees as a proportion of the total share capital of the company
<i>esopnum</i>	Number of times an employee share ownership plan is implemented in a listed company in a year

4. Evaluation and Analysis of Model Effects

After the models and indicators are constructed, the pre-processed data are brought into bag-boosting, ridge regression, and LSTM models for training. During the training process, to ensure that the training can meet the expectation, the mean squared error (MSE) value is used as the training effect evaluation function. The training effects of the combined bag-boosting model with different training times are shown in Figure 4.

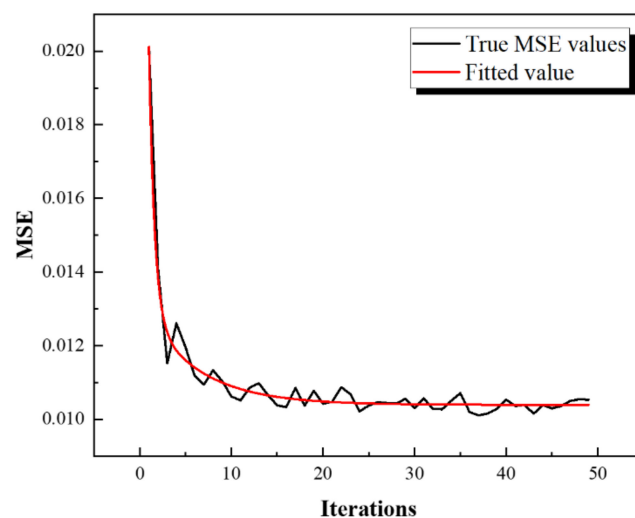


Figure 4. Training period about MSE.

Within the training cycle $[0,1,2,3,4,5]$, the MSE value has been in a decreasing trend with a large rate of decrease, which proves that the bag–boosting model adjusts the nodes and node weights drastically at this stage when integrating the CART tree. However, as the prediction period continues to increase, the rate of change of the MSE value slows down, and at this time the bag–boosting model is in the fine–tuning stage for internal nodes and weights, and after the MSE value reaches about 0.011 (reaching the expected value), the bag–boosting model stops training, proving that the model has reached the optimal state. After the training of the model was completed, the performance of the bag–boosting model was evaluated by predicting the real samples and comparing the prediction results of the model with those of the ridge regression and LSTM models. The comparison of the prediction effects of the three models is shown in Figure 5.

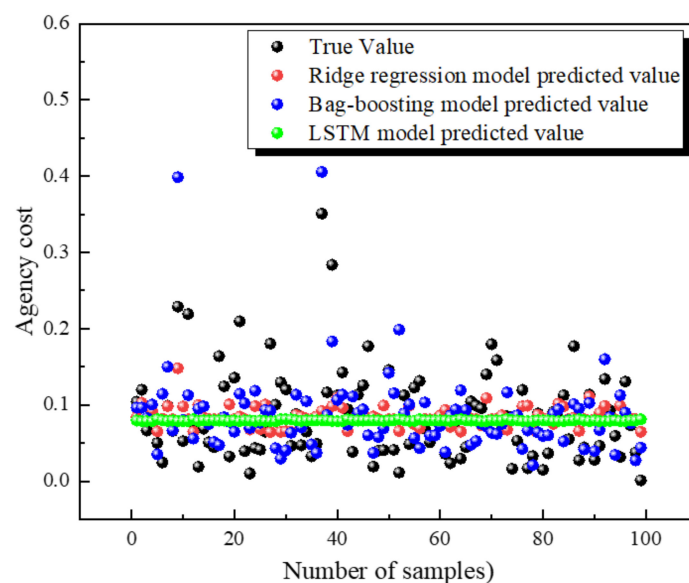


Figure 5. Prediction effect of different models.

Figure 5 shows the prediction scatter plots of the LSTM neural network, ridge regression, and bag–boosting models, respectively. It is easy to see that the predicted values of the LSTM model differ significantly from the true value distribution under the data structure of this paper, which means that the prediction effect of the model is poor. From the prediction results of the ridge regression model, we can see that the model can only simulate about 1/3 of the real values of the samples, and the prediction effect is average. The scatter plot of the prediction of the bag–boosting combined model proposed in this paper shows that the combined model can simulate most of the sample’s true values, and the prediction effect is better. Numerically, the predicted values of the LSTM model are distributed around 0.075, with a relatively smooth distribution and a large difference with the trend of the real values, and the model prediction effect is extremely poor. The prediction trend of the ridge regression model is also relatively small, and it is difficult to simulate the trend of the real value, and the model prediction effect is average. The trend of the predicted value of the bag–boosting model is generally consistent with the trend of the real value, and the model prediction effect is good. However, there are still a small number of intervals where the two trends do not fully match, which indicates that there is still room for improvement in the machine learning training model. Further improvements will be made in the optimization of the model later. The combined prediction effect of the three models shows that the combined bag–boosting model proposed in this paper has better prediction performance and a better fitting effect on the real value of the sample, which is an improvement of the existing model.

5. Impact of Different Factors on Agency Costs

5.1. Eigenvalue Correlation Analysis

After obtaining the trained model, the effect of each influencing factor on the agency cost of the firm remains unclear. For this reason, this paper is explored through the control variables method. Before exploring the mixed reform strategy and agency costs of SOEs, the correlation analysis of the characteristic variables selected in this paper is made first, and the correlation coefficients between the main variables are shown in Table 3 below.

Table 3. The correlation coefficient between main variables.

Variables	G&A	shr1th	shrt	k1th	catg	ebal	ifad	adnum	asnum	aenum	adrat	asrat	aerat	adserat	esop	imprat	esopnum
G&A	1.000																
shr1th	0.036	1.000															
shrt	0.057	0.407	1.000														
k1th	0.072	0.335	0.304	1.000													
catg	−0.114	0.017	−0.044	−0.013	1.000												
ebal	0.013	0.105	0.099	0.099	0.007	1.000											
ifad	−0.003	0.400	0.445	0.025	0.007	0.022	1.000										
adnum	0.001	0.390	0.464	0.016	−0.010	0.020	0.304	1.000									
asnum	−0.018	0.240	0.274	−0.015	−0.032	0.006	0.372	0.404	1.000								
aenum	0.016	0.199	0.283	0.001	−0.068	0.013	0.395	0.309	0.239	1.000							
adrat	0.005	0.386	0.455	0.007	−0.017	0.020	0.122	0.278	0.392	0.122	1.000						
asrat	−0.017	0.235	0.272	−0.012	−0.034	0.007	0.378	0.399	0.249	0.256	0.394	1.000					
aerat	0.026	0.184	0.266	0.002	−0.080	0.012	0.389	0.161	0.218	0.233	0.184	0.236	1.000				
adserat	0.008	0.357	0.440	0.001	−0.053	0.019	0.229	0.197	0.149	0.207	0.214	0.360	0.201	1.000			
esop	−0.012	0.040	0.041	0.001	0.018	0.000	0.021	0.010	−0.009	−0.002	0.013	−0.009	−0.001	0.003	1.000		
imprat	−0.014	0.019	0.021	−0.005	0.023	0.000	0.041	0.022	−0.007	−0.003	0.023	−0.008	−0.001	0.010	0.149	1.000	
esopnum	−0.003	0.010	0.022	−0.003	0.001	0.002	0.005	−0.001	−0.006	0.006	−0.002	−0.006	0.019	0.003	0.233	0.235	1.000

From Table 3, it can be seen that the correlation coefficients between the main characteristic variables are less than 0.5, which means that it can be assumed that there is no multicollinearity between the variables. Thus, regression analysis can be performed directly on all variables.

5.2. Exploring the Effect of the Hybrid Reform Strategy

This paper selects the sample data of SOEs in 2020, plots the scatter distribution of the indicators of mixed reform strategy and agency costs, and judges the effect of the selected indicators in reducing agency costs of SOEs from the trend of the sample distribution. Among them, the equity mix dimension selects the indicator of the shareholding ratio of the first largest non-state shareholder; the executive appointment dimension selects two indicators of the number and proportion of supervisors appointed by non-state shareholders; the employee stock ownership plan dimension selects the indicator of the dummy variable of plan implementation. The distribution trend is shown in Figure 6 below.

Figure 6a shows the trend of the distribution of the shareholding ratio of the first non-state shareholder introduced into the equity mix of SOEs and the agency costs. The overall distribution trend of the sample is consistent with the dark green dashed line, i.e., the agency costs of SOEs tends to decrease as the shareholding ratio of the first non-state shareholder increases, which indicates at this point that the introduction of the first non-state shareholder into the equity mix of SOEs plays a role in reducing the agency costs.

Figure 6b shows the distribution trend of dummy variables and agency costs for the implementation of the employee stock ownership plan, which shows that the SOE samples with higher agency costs did not implement the employee stock ownership plan, while the SOE samples that implemented the plan had an overall distribution of lower agency costs, which indicates that the implementation of employee stock ownership plan in SOEs' hybrid reform has realized the incentive for employees and improved their earning expectations [30], thus playing a role in monitoring and disciplining SOE managers and reducing the agency costs.

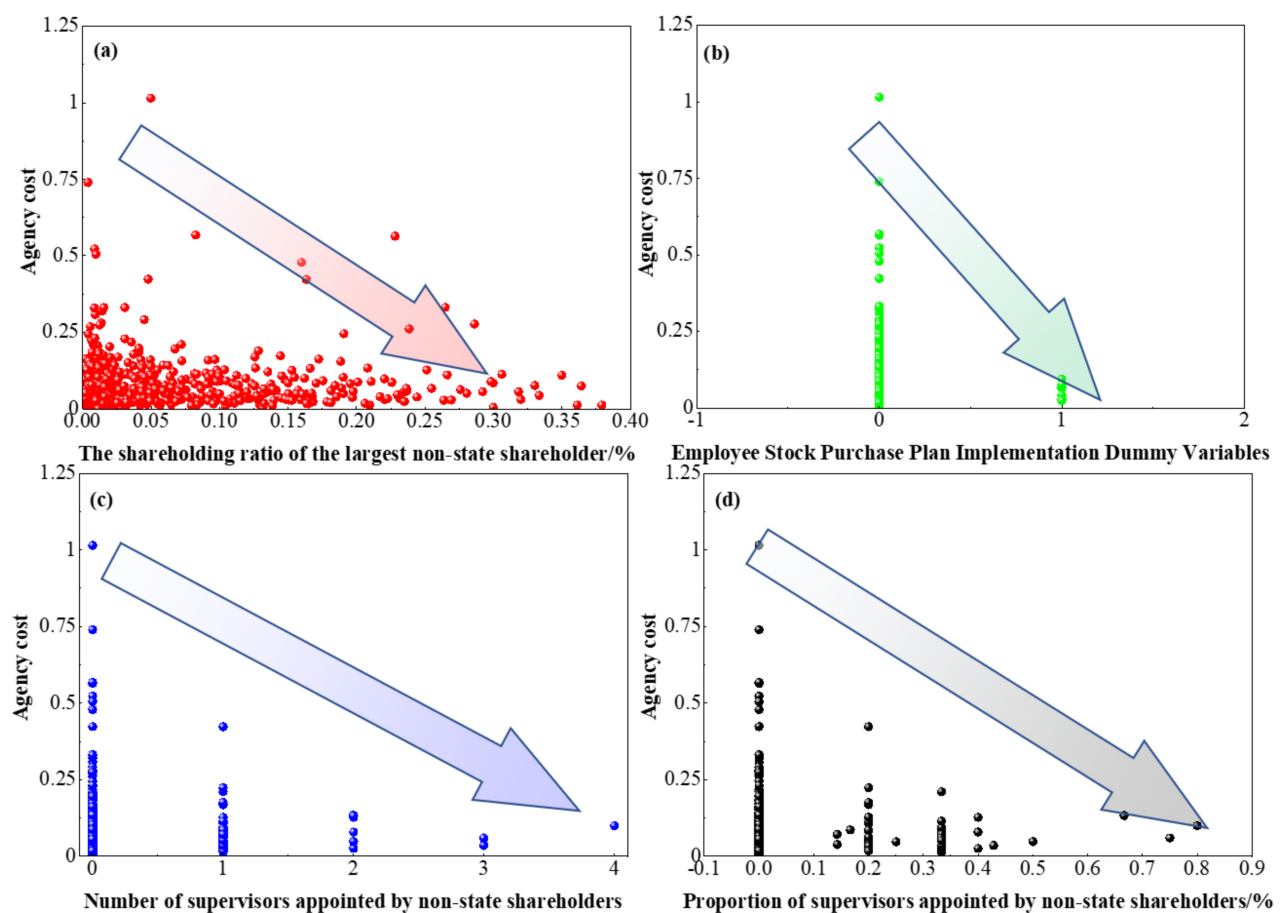


Figure 6. Effectiveness chart of the hybrid reform strategy: (a) shareholding ratio of the first largest non-state shareholder; (b) dummy variable for the implementation of employee share ownership plan; (c) number of supervisors appointed by non-state shareholders, (d) proportion of supervisors appointed by non-state shareholders.

Figure 6c,d show the distribution trend of the number of supervisors appointed by non-state shareholders versus agency costs, and the lower right panel shows the distribution trend of the proportion of supervisors appointed by non-state shareholders versus agency costs, which shows that the overall distribution trends of the sample are all consistent with the dark green dashed line, indicating that the intervention of non-state shareholders in the executive governance dimension can effectively play a supervisory role and reduce the agency costs of SOEs.

Synthesizing Figure 6, equity mix, executive assignments, and employee stock ownership plan implementation can all exercise the supervisory function of non-public capital on SOE management [20] and reduce SOE agency costs. In reality, three SOEs, Hong Kong Rongtong, Shanghai Film, and Guodun Quantum, have a low degree of hybridization and are in the high range of agency costs. This also supports the conclusion of this paper from the reverse direction.

5.3. Exploring the Optimal Ratio Setting of Hybrid Reform Strategy Indicators

In this paper, we focus on predicting the impact of the change of a single strategy feature value of the agency cost of an enterprise based on the bag-boosting combination model, and try to investigate the optimal ratio setting for the optimal effect of the hybrid strategy indicator. The range of feature value change refers to the maximum and minimum values of each feature value in dataset D, where the maximum value is taken to be no more than two times the maximum value of the reference feature value, and the feature change values are generated in the form of random numbers. To ensure the robustness of

the results, the other feature values are replaced by the average when exploring the effect of one of the feature values.

5.3.1. Exploring the Optimal Ratio Setting of Equity Blending Strategy Indicators

Below, Figure 7 predicts the relationship between the introduction of non-state shareholders in the top ten shareholders of SOEs' hybridization, the shareholding ratio of the first largest non-state shareholder, and the agency costs of SOEs. The black line indicates the predicted line of the true relationship between the two, and the red line is the line of the fitted relationship between the two. From the fitted relationship line, it can be seen that the effect of the shareholding ratio of the first non-state shareholder on the agency costs of SOEs generally shows a sin function trend, and the best incentive effect is achieved when the first non-state shareholder is introduced to hold 4.5–25.2% of the company's shares, at which time the non-state shareholder restrains the executives of SOEs and reduces the agency costs significantly. With the further increase in the shareholding of the first largest non-state shareholder, its voice in the enterprise also began to increase, and the motivation of non-state shareholders to take advantage of the special political resources of SOEs [3], build an interesting empire, and seek to maximize their interests gradually emerged, resulting in the escalation of agency costs of SOEs, but after its shareholding exceeded 50%, SOEs became privately held competitive enterprises, and the transfer of control affected corporate activities [31], government policy subsidies are subsequently reduced, and to ensure that enterprises maximize profits in their autonomous operations, the first largest non-state shareholder has a lower motive to encroach on the interests of the enterprise, and its decision goal is changed to maximize corporate value, at which time the agency costs of SOEs begin to show a downward trend.

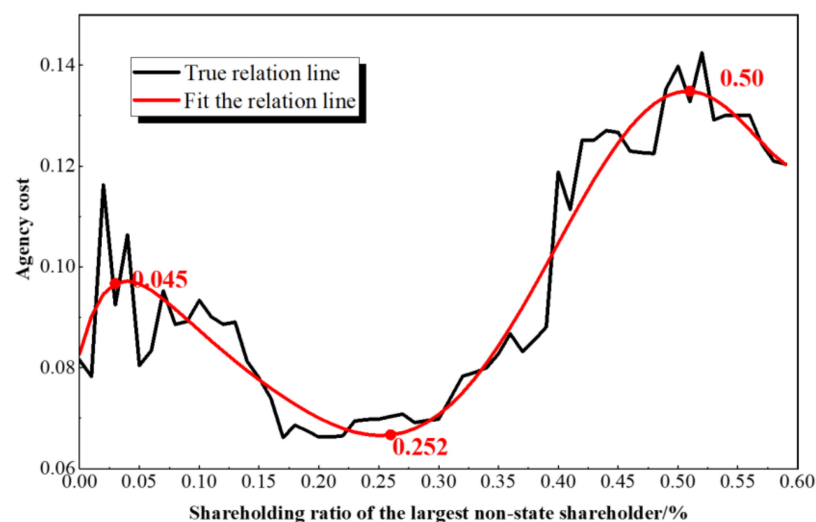


Figure 7. Shareholding ratio of the first largest non-state shareholder and agency costs.

Based on the results in Figure 7, if SOEs carry out mixed equity reform and need to continue to retain the nature of SOEs, the shareholding ratio of introducing the first major non-state shareholder should be kept between 4.5% and 25.2%, when the non-public capital has the best effect on suppressing SOE agency costs. If SOEs can achieve privatization and restructuring, the shareholding ratio of introducing the first major non-state shareholder should be higher than 50%, when the agency cost of the enterprise is in a downward trend.

5.3.2. Exploration of the Optimal Ratio Setting of Executive Assignment Strategy Index

Below, Figure 8 predicts the impact of the number of executive assignments and the proportion of assignments on the agency costs of introducing non-state shareholders into the mixed reform of SOEs. The curve line is the line fitting the relationship between the

number of appointed supervisors and agency cost, the green line is the line fitting the relationship between the number of appointed senior management and agency cost, the blue line is the line fitting the relationship between the proportion of appointed senior management and agency cost, and the red line is the line fitting the relationship between the proportion of appointed supervisors and agency cost.

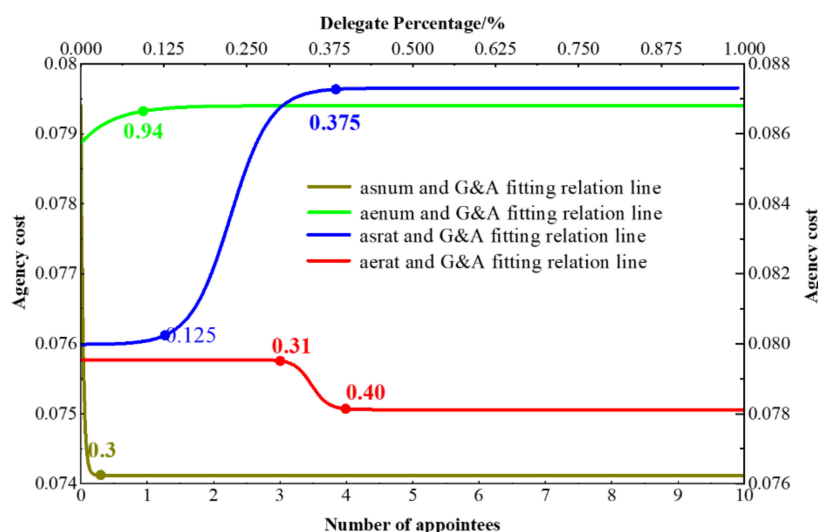


Figure 8. Number and proportion of executive assignments and agency costs.

As can be seen from the curve line in Figure 8, when the number of supervisors appointed by non-state shareholders exceeds 0.3, the agency costs of SOEs are maintained at the lowest level, at which time it indicates that the supervisors appointed by non-state shareholders into SOEs can play a supervisory role to restrain the behavior of executives and thus reduce the agency costs. The red line in Figure 8 shows that the proportion of supervisors appointed by non-state shareholders has a significant negative correlation with the agency costs of SOEs in general, and when the proportion of appointed supervisors reaches 40%, the appointed supervisors restrain the self-interest motive of SOE managers and suppress the agency costs of SOEs most significantly. The green line in Figure 8 shows that non-state shareholders assign top management to participate in the management of SOEs, and the assigned board of directors tends to use SOEs' special resources to make business decisions that maximize their interests, thus pushing SOEs' agency costs further up. The overall trend of the blue line in Figure 7 also confirms that the larger the proportion of top management appointed by non-state shareholders, the more prominent the agency problem of SOEs, and when the proportion of appointed top management reaches 37.5%, the agency costs of SOEs stabilizes at a higher level. Synthesizing the findings in Figure 8, non-state shareholders should appoint supervisors to SOEs, and the proportion of appointed supervisors should be higher than 40%. At the same time, to avoid the appointed top management from using special political resources of SOEs to maximize their interests, non-state shareholders should try to avoid directly appointing executives to participate in SOEs' business decisions.

6. Conclusions

To solve the problem of high agency costs of SOEs, mixed ownership reform was proposed in 2013 aiming to introduce non-state capital, improve the ownership structure of SOEs, and play the role of supervision and restraint of non-state shareholders on the agency behavior of SOE managers. There are three main strategies for the mixed reform of differentiated SOEs: first, equity mix; second, executive assignment; and third, employee stock ownership plan implementation. This paper constructs a bag-boosting combination model to test the impact of hybrid reform strategies on SOEs' agency costs and explores

the indicator ratio setting when the effect of hybrid reform strategies to reduce SOEs' agency costs is optimal, taking the A-share state-owned listed companies from 2008 to 2020 as a sample, and the study concludes. The following four main conclusions are drawn: (1) the introduction of non-state shareholders in the mixed reform of SOEs, in which the shareholding ratio of the first largest non-state shareholder has a sin function trend on the agency costs of SOEs, in order to avoid non-state shareholders using SOE resources to seek to maximize their own interests, their shareholding ratio should be set between 4.5% and 25.2%. When SOEs become private capital holding enterprises, the agency cost shows a decreasing trend. (2) Non-state shareholders appointing supervisors into SOEs will play a supervisory and restraining role in the behavior of SOE managers. After the proportion of appointed supervisors reaches 40%, the supervisors' duties under the supervisory effect will have a better suppression effect on the agency costs of SOEs; (3) The special nature of SOEs makes them enjoy government subsidies and other political resources, and when non-state shareholders appoint executives to truly participate in SOEs' business decisions, the self-interest of executives will make SOEs' agency costs rise, and when the appointment ratio reaches 37.5%, SOEs' agency costs remain stable at a high level. (4) After employees hold SOEs' shares and become shareholders, they actively exercise their supervisory functions to suppress SOEs' agency conflicts and thus reduce SOEs' agency costs.

Synthesizing the findings of this paper and the actual situation of mixed reform, the following suggestions are obtained: first, the government should improve the mixed reform system at the policy level, lower the threshold for non-state capital to enter SOEs, steadily advance the process of mixed reform of SOEs layer by layer, include the reform of SOEs in monopolistic industries, create a fair competitive market environment for non-state capital, and at the same time encourage non-state shareholders to actively play a governance role to improve the agency problem of SOEs. Second, in the process of deepening reform, SOEs should insist on adopting a mixed equity strategy, effectively motivate employees to hold company shares and participate in corporate governance, and in the process of promoting mixed reform, not only stay at the level of introducing non-state capital, but also substantially empower non-state shareholders and improve their right to appoint supervisors to SOEs, and non-state shareholders realize the combination of participation and control in order to effectively restrain SOE managers and achieve the purpose of mixed reform to reduce the agency cost of SOEs.

Corporate agency costs are the costs incurred between shareholders and corporate management due to the existence of a principal-agent relationship, that is, the cost of management managing the business in place of shareholders. Higher agency costs may create the right environment for management to play favorites and misappropriate corporate interests, which in turn may lead to impaired corporate performance. Lower agency costs, on the other hand, often mean that management can only receive lower returns, which may make management less motivated to fulfill the obligations of the principal-agent relationship and less willing to take the trouble to manage the enterprise, which may also lead to the impairment of the enterprise's interests, so it is necessary to explore the relationship between agency costs and corporate financial performance. However, different firms have different shareholders and different shareholding structures, and the shareholders' decision-making style and supervision may lead to different patterns of agency costs on financial performance among different firms, so subsequent studies will focus more on the relationship between agency costs and financial performance, and the role of shareholding structure in it.

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