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A Predictive Model of the Impact of Government Subsidies on the Performance of Agricultural Enterprises Based on Machine Learning Algorithms

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Abstract. Scientifically assessing the true effect of government subsidies on the performance of agricultural enterprises and deeply revealing its mechanism of action and restrictive factors holds significant theoretical and practical value for optimizing agricultural policy design, enhancing the efficiency of fiscal resource allocation, and promoting high-quality agricultural development. To precisely analyze this impact, this study innovatively designed a Transformer classification algorithm that integrates adaptive feature interaction and adversarial robustness. Through empirical testing with four sets of comparison models including random forest, decision tree, XGBoost, and CatBoost, the results show that in the benchmark model, XGBoost has the best predictive performance with an accuracy rate of 85.3%. However, the new model proposed in this paper has achieved significant improvements in key performance indicators: accuracy (Accuracy) increased by 3.6%, recall (Recall) improved by 4.3%, precision (Precision) rose by 3.9%, and the F1 score increased by 4.1%. This research not only provides advanced analytical tools and empirical evidence for a deeper understanding of the complex relationship between government subsidies and the performance of agricultural enterprises but also offers important data support and decision-making references for precise policy implementation to enhance subsidy effectiveness and promote agricultural modernization.

Keywords: Government subsidies, agricultural enterprise performance, machine learning.

1. Introduction

Agriculture, as the foundation and strategic industry of the national economy, its stability and development are directly related to food security, farmers' livelihoods and rural prosperity [1]. However, agricultural production is inherently confronted with challenges such as high natural risks, long cycles, and intense market fluctuations. Coupled with the low price elasticity of agricultural products, the profitability of agricultural enterprises is generally fragile, and their investment willingness is often insufficient. To ensure national food security, stabilize the supply of agricultural products, enhance agricultural competitiveness and promote rural development, governments around the world generally implement various forms of agricultural subsidy policies, including direct payment, price support, credit interest subsidies, insurance subsidies and technology promotion

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subsidies [2]. One of the core goals of these huge public financial investments is to improve the operating conditions and long-term performance of agricultural enterprises. Against this backdrop, systematically and scientifically assessing the true impact of government subsidies on the performance of agricultural enterprises, revealing their mechanism of action and restrictive factors, holds significant theoretical and practical significance for optimizing policy design, enhancing the efficiency of fiscal fund utilization, and achieving high-quality agricultural development [3].

Traditional research mainly relies on econometric models to analyze the statistical correlation between subsidies and enterprise performance. However, the performance of agricultural enterprises is influenced by multiple complex factors: the intensity and method of subsidies, the scale and nature of property rights of enterprises, the characteristics of managers, regional resource endowments, infrastructure conditions, market accessibility, climate change, international price fluctuations, and the supporting policy environment, etc. There are often nonlinear relationships, interaction effects and unobserved heterogeneity among these factors. Traditional methods face limitations when dealing with high-dimensional, nonlinear and heterogeneous data and mining complex patterns. Machine learning algorithms, with their powerful data processing and pattern recognition capabilities, provide revolutionary tools for deepening this research [4]. Firstly, in handling massive heterogeneous data, machine learning can effectively integrate structured financial data and unstructured data to build a more comprehensive enterprise profile and environmental feature library. Secondly, in terms of modeling capabilities, algorithms such as random forests, gradient boosting trees, support vector machines, and neural networks are adept at capturing complex nonlinear relationships and high-order interaction effects among variables, revealing patterns that are difficult for traditional linear models to discover [5]. Thirdly, in terms of causal inference and heterogeneity analysis, by integrating emerging methods such as causal forests and meta-learners, the differential treatment effect (HTE) of subsidies on different types of enterprises can be estimated with fewer preset conditions, providing data-driven decision-making basis for "precise subsidies". Fourth, the powerful predictive ability of machine learning can be used to simulate the possible changes in enterprise performance under different subsidy policy scenarios, assisting policymakers in conducting forward-looking evaluations and scheme comparisons. This paper designs an adaptive feature interaction and adversarial robust Transformer classification algorithm to analyze the impact of government subsidies on the performance of agricultural enterprises.

2. Data source

This dataset contains the operating conditions of 541 agricultural enterprises, including 10 characteristic variables such as government subsidy amount, proportion of R&D investment, number of employees, farm area, annual revenue, asset-liability ratio, operational efficiency, market share, geographical location advantage and management experience, as well as a binary target variable of whether the enterprise performance has significantly improved. Some datasets are selected for display, as shown in Table 1.

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Table 1. Physical properties of Al-9.6at%Sc alloy

Government_ Subsidy	R&D_Investment	Employee_ Count	Annual_Revenue	Operational_Efficiency	Location_Advantage	Management_Experience	Performance_Improvement
41.953	4.57	78	7.571	0.713	0.734	12	0
39.132	1.792	65	10.034	0.592	0.493	8	1
58.388	3.329	63	11.937	0.745	0.719	12	0
42.284	4.408	76	9.436	0.659	0.684	15	1
49.371	2.539	58	6.559	0.673	0.572	7	0
54.792	5.15	80	13.17	0.821	0.868	16	1
26.419	2.781	51	5.578	0.627	0.459	6	0
43.124	4.154	73	10.553	0.755	0.751	13	1
31.503	3.035	56	9.399	0.629	0.541	9	0
53.276	4.757	74	11.717	0.765	0.758	14	1

3. Methods

3.1. Transformer

Transformer is a revolutionary deep learning architecture that has completely transformed the field of sequence modeling. The network structure of the Transformer is shown in Figure 1. Its core lies in completely discarding the recurrent (RNN) or convolutional (CNN) structure and instead relying on the self-attention mechanism to capture the global dependency relationships among elements in the input sequence, regardless of how far apart they are. The model is mainly composed of stacked encoder and decoder layers [6]. The encoder is responsible for processing the input sequence, calculating the association strength between each element in the sequence and all other elements through the self-attention layer, and obtaining a representation that integrates rich context information. Then, nonlinear transformation is carried out through the feedforward neural network layer. The decoder is responsible for gradually generating the target sequence based on the output of the encoder and the part of the output sequence it has already generated. In the decoder, in addition to the attention to the encoder output, masking self-attention is also used to ensure that when generating the output at the current position, only the previously generated position information in the sequence can be focused on, preventing information leakage.

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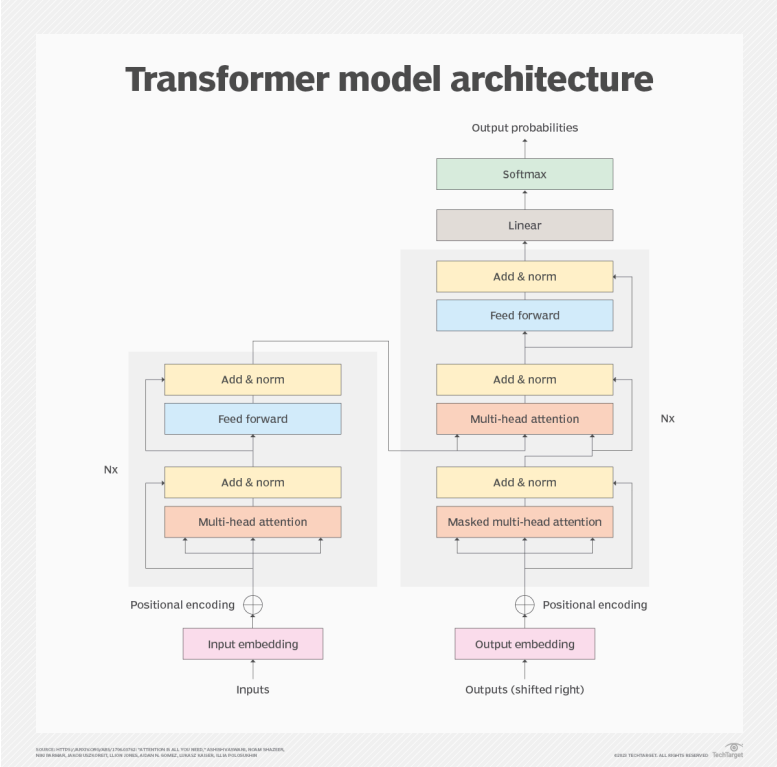

Figure 1. The network structure of the transformer

3.2. Adaptive feature

The algorithm designed in this paper has been deepened on the basis of the self-attention mechanism at the core of the Transformer, enabling it to go beyond simple feature association calculations. It adaptively assesses and selects the most discriminative interaction patterns among different feature dimensions during the attention calculation process by introducing dynamic gating mechanisms or learnable feature importance weights. This adaptability is reflected in the model's ability to dynamically adjust the intensity, range, and combination of feature interactions based on the unique context of the current input, thereby more accurately capturing complex [7] and nonlinear feature dependencies, avoiding noise caused by invalid or redundant interactions, and significantly enhancing the discriminative ability of feature representations [8].

3.3. Adversarial robustness

To enhance the model's resistance to maliciously constructed adversarial samples, the algorithm incorporates an adversarial training strategy during the training phase. Specifically, it applies carefully calculated small perturbations (adversarial perturbations) to the original input samples to generate adversarial samples, and then mixes these adversarial samples with the original samples and inputs them into the model for training [9]. More importantly, this adversarial training is not carried out in isolation but is deeply integrated into the attention layer and feature representation learning process of the Transformer. This forces the model to, when adaptively constructing feature interactions, not only focus on the discriminability of the original data but also simultaneously consider the stability of the features under adversarial perturbations. Thus, a robust feature representation that is insensitive to minor input variations is learned [10].

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4. Result

In terms of hardware configuration, a server equipped with 4 NVIDIA A100 80GB Gpus is used, along with an AMD EPYC 7H12 64-core processor and 256GB DDR4 memory. The software environment adopts Matlab R2024a. The core experimental parameters are set as: The Transformer encoder has 6 layers, a hidden dimension of 512, 8 attention heads, an adversarial training step size of ϵ=0.03, 3 iterations of PGD adversarial attacks, a feature interaction gate threshold γ=0.65, a batch size of 128, an initial learning rate of 3e-5, a weight decay coefficient of 1e-6, and a maximum training round of 100. Use the RAdam optimizer and insert an adaptive feature cross module before the classification layer.

This paper employs four sets of comparison models, including random forest, decision tree,XGBoost and CatBoost models, etc. The experimental evaluation parameters include Accuracy, Recall, Precision and F1, etc. The index evaluation results of the output model are shown in Table 2.

Table 2. The index evaluation results of the output model

Model	Accuracy	Recall	Precision	F1-Score
Decision tree	0.782	0.745	0.776	0.760
Random forest	0.826	0.802	0.831	0.816
CatBoost	0.843	0.821	0.847	0.834
XGBoost	0.853	0.832	0.861	0.846
Our Model	0.889	0.875	0.900	0.887

Output the comparison results of each model, as shown in Figure 2. From the experimental results, it can be seen that among the comparative test models, the XGBoost model has the highest prediction accuracy, reaching 85.3%. The model proposed in this paper, Our The model is 3.6% higher than XGBoost in Accuracy, 4.3% higher than XGBoost in Recall, 3.9% higher than XGBoost in Precision, and 4.1% higher than XGBoost in F1, which is beneficial for studying the impact of government subsidies on the performance of agricultural enterprises The influence of the effect is of great significance.

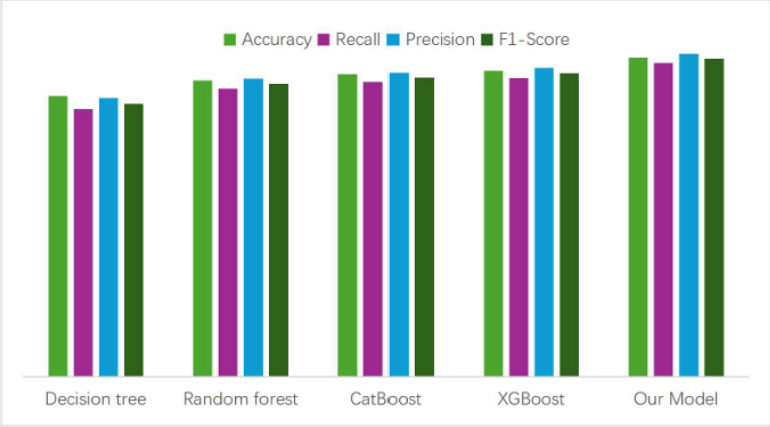

Figure 2. The comparison results of each model

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5. Conclusion

This study focuses on the issue of the impact of government subsidies on the performance of agricultural enterprises, which holds significant theoretical and practical value. Scientifically assessing its true effects, revealing the internal mechanisms and constraints, is a key link in optimizing the design of agricultural support policies, enhancing the efficiency of public financial resource allocation, and ultimately driving high-quality agricultural development. To break through the limitations of traditional econometric methods in capturing complex nonlinear relationships and high-dimensional feature interactions, this paper innovatively proposes an adaptive feature interaction and adversarial robust Transformer classification algorithm (Our model). Through rigorous experimental design, random forest, decision tree, XGBoost and CatBoost were selected as representative baseline models for comparative analysis. Empirical results show that in the baseline model, XGBoost exhibits the best performance, with a prediction accuracy of 85.3%. However, the model proposed in this paper has achieved systematic transcendence in the core evaluation indicators: Compared with XGBoost, it has improved Accuracy by 3.6 percentage points, Recall by 4.3 percentage points, Precision by 3.9 percentage points, and the overall F1 score by 4.1 percentage points. This significant improvement demonstrates the advantages of the new model in feature adaptive learning and robustness against noise, providing a powerful methodological tool for more accurately and reliably characterizing the complex correlation between government subsidies and enterprise performance.

The significance of this research lies not only in proposing a superior predictive model, but also in its profound implications for a deeper understanding of the actual effectiveness of government subsidy policies. The systematic improvement of model performance means that it can more sensitively identify the key features of the effectiveness of subsidy policies, more accurately capture the performance change patterns of subsidy-benefiting enterprises, and more stably resist the interference of data noise. This provides unprecedented analytical accuracy and credibility for revealing the true path, intensity, and potential heterogeneity (such as the differences in impact on enterprises of different scales, types, or regions) and constraints (such as supporting policies, market environment, and enterprise management capabilities) of government subsidies on the performance of agricultural enterprises. Therefore, the methodological framework and empirical findings constructed in this study provide solid quantitative basis and decision support tools for policymakers to scientifically assess the effectiveness of existing subsidies, accurately identify the key links and bottlenecks of policy effects, and thereby design a more targeted, efficient, and better stimulating fiscal support system for the intrinsic motivation and innovation vitality of agricultural enterprises. It has significant practical guiding value for maximizing the utilization efficiency of fiscal funds supporting agriculture and achieving high-quality and sustainable development of the agricultural industry. This research has built a more precise bridge connecting the assessment of the micro-effects of policy intervention with the macro strategic goals of agricultural development.

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