Article

Research on the Transfer of Rural Land Contracting Rights: Empirical Analysis Based on Shandong Province

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Abstract: This study investigates the transfer of rural land contracting rights in Shandong Province, China, employing a mixed methods approach that integrates qualitative policy analysis and quantitative multiple linear regression models based on panel data from 16 prefecture-level cities (collected in 2010–2022). The findings demonstrate that land transfer optimizes resource allocation, enhances agricultural output efficiency, and serves as a critical mechanism for advancing agricultural modernization and rural revitalization. Key drivers, such as agricultural modernization and industrial development, significantly promote land transfer, particularly in coastal areas, while challenges like non-standardized contracts and inadequate farmer protections persist. The study proposes targeted strategies, including strengthening agricultural modernization, enhancing farmer income through non-agricultural industries, and improving institutional frameworks to stabilize the land transfer market. Additionally, it highlights the potential role of rural social workers in addressing contentious issues such as women's rights, displacement, and access to resources, ensuring equitable and sustainable rural development. These measures aim to accelerate agricultural modernization, promote rural economic growth, and enhance the competitiveness and social well-being of rural areas, providing a robust foundation for policy formulation.

Keywords: transfer of rural land contracting rights; agricultural modernization; farmers' income; industrial development; sustainable development

1. Background and Significance of the Study

1.1. Research Background

Under China's current land system, rural land is divided into three categories: agricultural land, construction land, and unused land [1]. Agricultural land is mainly used for agricultural production, including arable land, forest land, grassland, etc.; construction land is used for non-agricultural purposes, such as industrial, commercial, and residential construction. According to the Land Management Law of the People's Republic of China, the conversion of agricultural land to construction land is subject to a strict approval process to ensure farmland protection and food security. Farmers have the right to contract management (long-term use right) of collectively owned land, usually for 30 years, and can transfer the management right (short-term use right) of the land to other entities such as farmers, cooperatives, or agricultural enterprises for a certain period of time, but cannot change the agricultural use of the land [2].

The state has strict restrictions and approval procedures for the conversion of agricultural land into construction land, and no unit or individual may change the use of agricultural land without authorization [3]. Specifically, the conversion of agricultural land into construction land requires the approval of the people's government at or above the county level, and the approval of the government at a higher level is required for the conversion of agricultural land to construction land. When the land needs to be converted from agricultural use to non-agricultural use, reasonable economic compensation must be made to the original land users, and their legitimate rights and interests must be protected.

In this process, local governments play a key role in reviewing and approving applications for the conversion of agricultural land to construction land, and supervising the standardized operation of the rural land transfer market to ensure that rural land transfer meets the requirements of laws and regulations. Collective economic organizations (such as village committees) also play an important role in land transfer, coordinating the distribution of benefits among villagers, safeguarding farmers' rights and interests, and ensuring that the land transfer process is open and transparent. As direct users of land, farmers have the right to decide whether to participate in rural land transfer and to choose suitable objects for land transfer, and can transfer the land management rights to others by signing a formal contract, but cannot change the agricultural use of the land. China's Land Management Law, Rural Land Contract Law, and other laws and regulations clearly stipulate specific provisions on rural land transfer and change of use, providing a legal basis and operational guidelines for land transfer.

In China's rural land system, the "transfer of rural land contract management rights" refers to the act of farmers transferring their contracted land management rights to other rural households, cooperatives, or agricultural enterprises within a certain period of time, rather than the change of land ownership [4]. Specifically, the land use remains unchanged, that is, the land is still mainly used for agricultural production activities such as growing crops and breeding, and its agricultural use will not be changed due to transfer. In this process, the farmer retains the right to contract the land (i.e., the right to use it for a long time) but transfers the right to operate the land (i.e., the right to use it for a short period of time) to others for rent or other forms of income. The recipient can use the land for large-scale, intensive agricultural production.

As a key element in the reform of China's rural economic system, the transfer of rural land contracting rights is not only a key driver to promote the process of agricultural modernization, but also one of the cornerstones of the implementation of the rural revitalization strategy. Jin Zhiwen pointed out that the implementation of the land transfer mechanism not only promotes the modernization and transformation of agricultural production mode, but also effectively improves the economic income of farmers, which plays a key role in promoting the long-term stable growth and sustainable development of the rural economy [5].

Since the beginning of China's rural reform movement in the 1980s, the rural land transfer mechanism, as a core institutional innovation, has gradually evolved into an important force driving rural economic development with the acceleration of agricultural mechanization and the significant improvement of production efficiency [6,7]. In particular, in 2013, the introduction of the "separation of powers" system, which clarified the separation of land ownership, contracting rights, and management rights, gave farmers the flexibility to flexibly transfer management rights on the premise of retaining the contracting rights, thereby promoting large-scale management and intensive use of land, and significantly improving agricultural production efficiency and resource utilization [8]. This policy innovation has effectively improved the efficiency of the allocation and use of land resources by establishing a legal basis and institutional framework. In the context

of China's land system, "land contracting right", "land management right", and "land use right" are three distinctly defined concepts. Specifically, the "land contracting right" refers to the rights of households to legally possess, use, and benefit from the farmland, forestland, grassland, etc., that they contract for operation. This right is typically long-term and protected by law, preventing arbitrary deprivation. When households retain their ownership or contracting rights to the land but transfer the actual farming rights to others, it involves the "land management right"; that is, without changing the original land contracting relationship, households can transfer the operational rights of their contracted land to other entities, achieving flexibility in land utilization. The term "land use right", on the other hand, encompasses a broader concept that not only includes the aforementioned two types of rights but also specifically refers to the usage rights on urban state-owned land. The reform of rural land systems also addresses how to better define and protect farmers' land rights, including but not limited to the redistribution of economic benefits and changes in rural social structures. Clearly understanding the distinctions among these three concepts is crucial for formulating and implementing effective rural land policies. These different layers of rights work together to ensure the basic rights of households while also facilitating the efficient allocation of land resources.

Since 2023, the annual "No. 1 Document" of the Central Committee of the Communist Party of China and the State Council has continued to focus on the reform of the rural land system, with special attention to the improvement and implementation of the rural land transfer mechanism. According to paragraph 22 of the No. 1 Central Document of 2023 "Core Strategies and Measures of the Central Committee of the Communist Party of China and the State Council on Comprehensively Promoting Rural Revitalization", it is clearly stipulated that the organized transfer of land management rights will be promoted, aiming to promote the large-scale operation of agricultural production. The policy aims to standardize the transfer of land management rights to promote the process of large-scale agriculture, with the goal of improving agricultural production efficiency, increasing farmers' income, and accelerating the modernization and transformation of the rural economic system, thereby supporting the effective implementation of the rural revitalization strategy [9]. In local practice, the main goal of the strategy is to systematically deal with the problem of farmland dispersion with the help of farmland integration and land consolidation methods based on farmers' independent choice. This approach focuses on the active participation of rural households and advocates organized land aggregation and optimization, aiming to improve land use efficiency and agricultural output benefits [10,11]. Such policies have accelerated the growth of the rural land transfer market and effectively promoted the integration and rational distribution of rural land resources.

However, with the deepening of policy implementation and the emergence of characteristics in the context of the new era, rural land transfer has encountered a series of complex problems in practice. In China, the acceleration of new urbanization and urban–rural integration has triggered significant socio-economic changes, which are manifested in the large-scale migration of rural labor to urban areas [10]. This dynamic has not only led to the intensification of the phenomenon of "hollowing" and "aging" in rural areas, but has also been accompanied by the problem of a large amount of cultivated land facing idle or reduced resource use efficiency. At the same time, the modern agricultural industry has an increasingly prominent need for technological innovation and mechanical automation upgrading, and the traditional decentralized business model has been difficult to adapt to and meet the practical needs of efficient and intensive agricultural production [12].

Land transfer is regarded as one of the key strategies for solving the current challenges, and has significantly improved agricultural productivity and accelerated the optimization and upgrading of agricultural industrial structures by aggregating land resources,

implementing large-scale production, and promoting the modernization of the agricultural industrial system. Studying this question is helpful for understanding how to promote land transfer from different perspectives, help the rural economy adapt to the new needs in the context of new urbanization, and ensure that farmers' rights and interests are effectively protected [13].

Shandong Province is located in the eastern coastal region of China and is an important province in China. Not only is it rich in natural resources and has a long history and culture, but it also occupies a pivotal position in terms of economy and agriculture. With a total area of about 158,000 square kilometers and a population of more than 100 million, Shandong Province is the second largest province in China. Since 1960, Shandong Province has achieved rapid economic growth and social development, becoming one of the pillars of China's economy despite a dramatic decline in population due to war and famine.

Shandong Province is known for its well-developed agricultural, industrial, and service sectors. In terms of agriculture, Shandong is an important grain production base in China, growing mainly wheat, corn, peanuts, and other crops. At the same time, Shandong is also one of the main areas of fruit, vegetable, and flower production. In terms of industry, Shandong has a strong manufacturing base, covering many fields such as chemicals, machinery manufacturing, and textiles. In addition, Shandong has also actively promoted the development of the service industry, especially in the tourism and modern logistics industries.

As one of the major agricultural provinces in China, the development of rural land transfer in Shandong Province reflects the process and characteristics of China's rural economic reform. Although the scale of land transfer has increased significantly recently, problems such as land fragmentation and the non-standardized operation of the land transfer market are still widespread, which limit further optimization and improvement of agricultural productivity [14]. Shandong Province was chosen for its prominence in terms of population size and economic importance.

The second most populous province, with a population of more than 100 million, has experienced rapid economic growth since 1960, especially after experiencing a significant reduction in population due to war and famine. The province not only has an important position in agriculture, but also shows strong momentum in areas such as industry and services. Therefore, it is of great significance to study the problem of land transfer in Shandong Province to understand the overall situation of China's rural economic reform. At the same time, most of the previous studies on land transfer have focused on macro policy analysis or micro case studies, and there are few systematic empirical studies on Shandong Province, a large agricultural province. The regional empirical analysis in this study fills this gap and provides a new perspective for understanding the actual operation mechanism of land transfer in different regions. In view of this, this paper takes Shandong Province as a case study and conducts an empirical analysis to explore the factors driving land transfer, identify the key factors influencing the process of land transfer, and then put forward targeted policy recommendations that have significant theoretical and practical value for deepening the understanding and practice of China's rural land system reform. In the context of promoting the development of modern agriculture, land transfer has become a focus of government management departments and academic circles. Previous academic literature comprehensively discussed the issue of rural land transfer, covering key areas, such as the legal framework, transfer mechanisms, diversified transfer forms, protection of farmers' interests, construction of the transfer market, and integration with urban–rural integration, with the goal of improving the efficiency of resource allocation, ensuring the realization of farmers' rights and interests, and promoting the process of agricultural modernization. On the basis of drawing on the existing academic research results, combined

with the latest policy guidance and empirical research, this paper will explore the factors affecting the process of rural land transfer and the problems associated with the process of rural land transfer in order to provide a scientific basis and policy suggestions for promoting healthy and orderly development of rural rural land transfer, and then contribute academic wisdom to support the implementation of the rural revitalization strategy and promote the process of agricultural and rural modernization.

To better illustrate the geographical scope covered in this study, Table 1 lists and provides a brief summary of the 16 prefecture-level cities in Shandong Province.

Table 1. Description of the 16 prefecture-level cities in Shandong Province.

City	Area (sq km)	Population (10,000 People)	Arable Land (Hectares in Thousands)	Major Agricultural Products
Jinan	8177	950	342.58	Wheat, corn, vegetables
Qingdao	11,282	1007	427.55	Fruits, teas, flowers
Zibo	5965	470	158.02	Apples, pears, grapes
Zaozhuang	4563	386	201.35	Peanuts, wheat, corn
Dongying	7923	217	217.39	Cotton, soybeans, wheat
Yantai	13,746	710	351.35	Apples, grapes, peanuts
Weifang	15,859	938	657.01	Vegetables, fruits, grains
Jining	11,187	836	501.97	Wheat, corn, cotton
Tai'an	7762	564	282.95	Fruits, vegetables, wheat
Weihai	5797	283	162.55	Fruits, teas, flowers
Sunshine	5310	287	180.74	Tea, peanuts, apples
Linyi	17,184	1124	628.17	Wheat, corn, peanuts
Texas	10,356	579	634.49	Wheat, corn, cotton
Liaocheng	8715	609	514.48	Wheat, corn, cotton
Binzhou	9457	395	385.60	Wheat, corn, cotton
Heze	12,239	880	768.98	Wheat, corn, cotton

1.2. Research Significance

1.2.1. Theoretical Significance

With the gradual completion of land rights confirmation, the transfer of rural land contracting rights has become an important driving force for the development of modern agriculture and the transformation of the rural economy. At present, China's agriculture is in a critical period of transformation from small-scale farmers to large-scale operations, and land transfer, as the core mechanism for optimizing the allocation of land resources and improving agricultural production efficiency, has attracted much attention [15]. However, most of the existing studies focus on policy frameworks and macro-level discussions, and lack systematic regional empirical analysis. The factors influencing land transfer have not been fully theoretically elaborated and verified by data, especially in a representative agricultural province such as Shandong Province.

The theoretical significance of this study is that, combined with the theory of optimal allocation of resources and the theory of economies of scale, and through the empirical analysis of 16 cities in Shandong Province, the factors influencing land transfer in rural areas of Shandong Province and the degree and effect of their influence are clarified, the current level of rural land transfer is re-examined, trends and existing problems are analyzed, and countermeasures and suggestions are put forward. The study enriches the empirical research content at the mesoscopic level, strengthens the evidence chain of the combination of land transfer theory and practice, and provides an empirical basis for follow-up research on the impact of rural land system reform on farmers' livelihood patterns, changes in rural social structure, and evolution of agricultural industrial structure, which has corresponding theoretical significance.

1.2.2. Practical Significance

As an important part of China's agriculture, the development of rural land transfer in Shandong Province has a certain exemplary role for the whole country. In the context of the current large-scale loss of the rural labor force and the rising demand for agricultural mechanization, realizing the intensive and large-scale utilization of land through rural land transfer has become an urgent problem to be solved. With the second round of land contracts about to expire in 2023–2027, how to further improve the institutional design of rural land transfer after the completion of land rights confirmation to ensure farmers' rights and interests, and the effective use of land resources, has become a key issue in policy formulation [15].

Through empirical analysis of the factors influencing rural land transfer in Shandong Province, this study puts forward suggestions and solutions for the institutional design and policy optimization of rural land transfer, and clarifies the current experience and problems associated with rural land transfer. At the time of the launch of a new round of land contract cycle, it is hoped that it can promote the healthy development of the rural land transfer market, protect the land rights and interests of farmers, promote the efficient use of land resources and the intensive and modern transformation of agricultural production, and ensure the smooth transition and effective docking of the reform of the rural land system.

2. Theoretical Framework

This study explores the impact of the transfer of rural land contracting rights on agricultural productivity based on the theory of optimal allocation of resources and the theory of economies of scale. These two theories provide important theoretical support for understanding the internal mechanism and effect of land transfer.

2.1. Theory of Optimal Allocation of Resources

The theory of optimal allocation of resources is derived from the basis of economics, focusing on the use of market mechanisms and institutional design to ensure the efficient allocation of limited resources in various applications, aiming to maximize the efficiency of resource utilization [16]. Adam Smith's theory of the "invisible hand" and the concept of Pareto optimality both focus on the efficiency of resource allocation.

In the field of agricultural economics, the theory of optimal allocation of resources focuses on how to achieve the most efficient integration of key resources such as land, manpower, and capital in the crop production process [17]. In view of the limited and non-repeatable nature of land resources, the application of effective institutions and market mechanisms is crucial to improve the efficiency of land resource allocation, which is the core of enhancing agricultural output capacity.

The core of the theory of optimal allocation of resources lies in the scarcity of resources: resources are limited, and trade-offs must be made between different uses. Resource allocation efficiency uses the market price mechanism or institutional arrangement to achieve optimal allocation of resources among different subjects and uses, so that the resource utilization efficiency can be maximized. Institutional influence: institutions and policies have an important impact on resource allocation, and good institutional arrangements can reduce transaction costs and improve the efficiency of resource allocation [18].

The theory of optimal allocation of resources is embodied in the following aspects during the process of transfer of rural land contracting rights: First, the redistribution of land resources. Through rural land transfer, land is transferred from rural households with low production efficiency to business entities with higher production efficiency, so as to realize the optimal allocation of land resources. Secondly, it can improve the efficiency of land use, and the transfer of rural land can promote the concentration and large-scale

operation of land, so that advanced agricultural technology, machinery, and equipment can be applied, and the yield rate of land can be improved. Thirdly, the allocation of labor is optimized. Some rural households transfer labor to non-agricultural industries following land transfer, which improves the efficiency of labor allocation in the whole society [18].

In this study, the theory of optimal allocation of resources provides a theoretical basis for analyzing the impact of rural land transfer on agricultural productivity in Shandong Province. Through empirical analysis, we can verify whether the optimal allocation of land resources promotes rural land transfer, and how institutions and policies (such as land ownership confirmation and land transfer market construction) affect the optimal allocation of resources, so as to provide guidance for proposing reasonable policies.

2.2. Theory of Economies of Scale

The theory of economies of scale has its origins in classical economics and expands on Adam Smith's theory of division of labor. Economies of scale refers to the economic phenomenon that, within a certain range, the production cost per unit of product decreases and the production efficiency increases with the expansion of production scale. Alfred Marshall further systematically elaborated the concepts of internal and external economies of scale in the Principles of Economics [19].

In the agricultural economy, economies of scale are reflected in the fact that large-scale and intensive management of agricultural production can bring about cost reduction and efficiency improvement.

The core of the theory of economies of scale lies in the following: fixed cost allocation—with the expansion of production scale, fixed costs can be allocated to more products, reducing unit costs; specialization and division of labor—the expansion of scale contributes to the specialization of the production process and improves labor productivity; technology and equipment utilization—large-scale operation can make full use of advanced technology and equipment, and improve production efficiency [20].

In the process of the transfer of rural land contracting rights, the theory of economies of scale is reflected in the following aspects: first, the centralized management of land, through the transfer of land, to achieve large-scale operation of land to create conditions for mechanization and modern agricultural production; second, to reduce production costs—large-scale operation can reduce the production cost per unit of land and improve profitability; and third, to promote the application of technology—large-scale operators are more able and willing to adopt advanced agricultural technologies and equipment to improve production efficiency [21,22].

In this study, the theory of economies of scale provides theoretical support for the analysis of how land transfer can improve agricultural productivity through large-scale operation. Empirical analysis can test whether the expansion of agricultural operation scale promotes land transfer and whether the large-scale operation has promoted the application of agricultural technology and the improvement of production efficiency.

2.3. Comparative Analysis

Although both the theory of optimal allocation of resources and the theory of economies of scale support that land transfer can improve agricultural productivity, they have different emphases and provide an understanding of the mechanism of land transfer in different dimensions. The following sections elaborate on these two theoretical perspectives and their application to land transfer and explore the more comprehensive understanding that can be brought about by combining these two theoretical perspectives.

Theoretical perspective of optimal allocation of resources

The theory of optimal allocation of resources focuses on ensuring the effective allocation of resources through market mechanisms and institutional design, emphasizing the rational allocation of resources among different uses, especially for scarce land resources, with the aim of improving overall social welfare. This theory emphasizes the following aspects in rural land transfer:

Resource scarcity and trade-offs: As a finite resource, how to effectively allocate land in different agricultural activities is a key issue [23]. The transfer of land from inefficient users to efficient users can be realized through land transfer, thereby improving the overall efficiency of land use.

The importance of institutional design: Good institutional design (such as land rights confirmation, standardization of land transfer markets, etc.) can reduce transaction costs and promote the efficient flow of resources [24]. For example, a clear definition of land rights can help enhance farmers' confidence in land transfer, thereby increasing their enthusiasm for land transfer.

Maximization of social welfare: By optimizing the allocation of resources, it not only improves the efficiency of agricultural production but also promotes the rational flow of rural labor so that some rural households can engage in non-agricultural industries, thereby improving the overall social welfare [25].

Theoretical perspectives on economies of scale

In contrast, the theory of economies of scale focuses on reducing costs and improving efficiency by expanding the scale of production. It is especially applicable to the promotion of mechanized operations in agricultural production and aims to improve the economic efficiency of individuals or enterprises. The theory of economies of scale emphasizes the following points in land transfer:

Fixed cost allocation: As the scale of production increases, the fixed cost per unit of product decreases. For agricultural production, large-scale operation can make more efficient use of large agricultural machinery and modern technology, thereby reducing labor costs and overheads per unit area.

Specialization and division of labor: Large-scale operation is conducive to the specialization of the production process and the refinement of the division of labor, thereby improving labor productivity. For example, a specialized growing team is able to better grasp the cultivation techniques of a specific crop, further improving yield and quality.

Technology and equipment utilization: Large-scale operation provides conditions for the use of advanced agricultural technology and equipment, which can not only improve production efficiency but also improve product quality and enhance market competitiveness.

Combining two theoretical perspectives

By combining the theory of optimal allocation of resources and the theory of economies of scale, we can provide a more comprehensive framework of understanding to guide subsequent empirical analysis and put forward targeted policy recommendations:

Understanding of comprehensive effects: The theory of optimal allocation of resources emphasizes the potential of rural land transfer in optimizing the allocation of land resources and improving land use efficiency. The theory of economies of scale, on the other hand, shows the possibility of reducing production costs and improving production efficiency by expanding the scale of operations. Combining the two can not only improve the economic efficiency of individual farms but also promote the modernization of agriculture in the entire region.

Identification of potential challenges: The theory of optimal allocation of resources reminds us of the importance of institutional design, and the lack of effective institutional arrangements may lead to information asymmetry and increased transaction costs in the process of land transfer. On the other hand, the theory of economies of scale suggests that

large-scale operations may face the problem of increased management and coordination costs. For example, as farms scale, so does the complexity of management and coordination, which may negate some of the economies of scale.

Formulation of policy recommendations: Based on the above analysis, policymakers should pay attention to improving the design of relevant systems for rural land transfer, including but not limited to land ownership confirmation and standardized construction of the land transfer market. At the same time, they should encourage and support the development of moderately large-scale operations, provide corresponding technical support and services, and help solve the management and technical problems encountered in the process of large-scale operations.

3. Research Methods and Data Sources

This study comprehensively uses qualitative and quantitative analysis methods to explore the issue of the transfer of rural land contracting rights. The qualitative research focuses on the policy environment, institutional analysis, and literature review. The quantitative study relies on the panel data for 16 cities in Shandong Province and uses statistical methods to carry out empirical analysis.

3.1. Qualitative Research Methods

Analysis of Policy Documents

The qualitative study first analyzes the policy documents on the transfer of rural land contracting rights issued by the state and Shandong Province in recent years, including the No. 1 Document of the Central Committee, the Rural Land Contract Law, and the relevant policy documents of the Shandong Provincial Government. Through the interpretation of these documents, the evolution path, policy objectives, and policy measures of China's rural land transfer policy are sorted out, and their impact on the actual operation and effect of rural land transfer is discussed. Analysis of the policy documents is helpful for understanding the key elements in institutional design and policy implementation, and provides institutional background support for subsequent quantitative analysis.

3.2. Quantitative Research Methods

3.2.1. Data Collection and Sources

The quantitative study is based on panel data from 16 cities in Shandong Province, with the following sources:

Statistical yearbook: contains macro data such as total power of agricultural machinery and gross agricultural production, and provides an understanding of the overall situation of rural land transfer in Shandong Province.

The government makes public data related to land transfer released by the Shandong provincial government and local municipal governments, providing an understanding of the effect of policy implementation and land use.

3.2.2. Model Construction and Variable Setting

In order to analyze the factors influencing land transfer, a multiple linear regression model was constructed. The model selects the proxy variable of the scale of transfer of rural land contracting rights (total power of agricultural machinery) as the dependent variable, takes the three index systems of agricultural modernization, farmers' income, and industrial development as the main independent variables, and includes the control variables of urbanization level, per capita GDP, proportion of output value of primary industry, and per capita education expenditure. The purpose of the model is to reveal the factors affecting land transfer, their relationship, and their impacts.

Multiple linear regression models

The objective is to analyze the factors influencing the scale of land transfer. To this end, we construct the following multiple linear regression model:

$$Yi = \beta 0 + \beta 1 Xi1 + \beta 2 Xi2 + \ldots + \beta n Xin + \varepsilon i$$

where *Yi* represents the scale of land transfer in the iith region (with the total power of agricultural machinery as a proxy variable); *Xi*1, *Xi*2, ..., *Xin* represent the independent variables, such as agricultural modernization level, farmers' income, industrial development, urbanization level, per capita GDP, proportion of primary industry output value, and per capita education expenditure, respectively; *β*0, *β*1, ..., *βn* are the parameters to be estimated; and *εi* is the error term.

3.2.3. Data Analysis Methods

The data were analyzed using STATA IBM SPSS Statistics 27 statistical analysis software.

Descriptive statistical analysis aims to provide the basic characteristics of the data, including the mean, standard deviation, and minimum and maximum values of the main variables, etc., to help explain the distribution of the data.

Mean: calculates the average value of each variable to reflect the concentrated trend of the variable.

Standard Deviation: a measure of the dispersion of the values of a variable, with larger standard deviations indicating greater fluctuations in the data.

Minimum and Maximum: Identify data ranges and show what is going on with extreme values.

Sample size (N): Confirms the sample size to ensure the validity of the analysis.

Correlation analysis, through the correlation coefficient matrix, is used to identify the correlation between variables and to provide preliminary support for regression analysis.

A Pearson's or Spearman's correlation coefficient matrix was used to identify the correlation between variables and to evaluate the strength of the linear relationship between different variables as follows.

Pearson's correlation coefficient: Applies to continuous variables and measures the linear relationship between two variables. The value range is [−1, 1], and the closer the absolute value is to 1, the stronger the correlation.

Spearman's correlation coefficient: Suitable for non-normally distributed or ordinal variables, calculated based on the rank of the variable.

Regression analysis involves the construction of multiple linear regression models, the examination of the influence between variables, and the control of year and region fixed effects to eliminate temporal trends and regional heterogeneity.

Generalized Least Squares (FGLS): used to deal with possible heteroskedasticity problems and improve the accuracy of model estimation.

Fixed-effect model: Controls for annual and regional fixed effects, eliminating temporal trends and regional heterogeneity.

Heterogeneity analysis was carried out by grouping regression (110 samples from coastal areas and 77 samples from inland areas) in coastal and inland areas to explore the impact of regional differences on agricultural mechanization.

The robustness test uses the Generalized Least Squares (FGLS) method to solve the heteroskedasticity problem and verify the stability of the core variables. The generality of the conclusions is further tested by regional regression.

3.2.4. Expected Results and Contributions

The purpose of this paper is to explore the factors influencing the transfer of rural land contracting rights using quantitative research methods and to identify the main variables driving rural land transfer and the problems existing in the process of rural land transfer. The data generated will support decision-making by policymakers, promote the effective operation of rural land transfer, and contribute to agricultural modernization and the prosperity of the rural economy.

By combining qualitative and quantitative research methods, this paper comprehensively analyzes the influencing factors and existing problems associated with the transfer of rural land contracting rights from multiple viewpoints, including policy background, institutional analysis, and empirical data, and puts forward corresponding policy suggestions. Qualitative research provides institutional and policy background support, while quantitative research verifies theoretical hypotheses, thus ensuring the comprehensiveness and scientific nature of the research.

3.2.5. A Comprehensive Understanding of the Inner Mechanism
Data Source

This section systematically describes the data sources, variable definitions, and measurement methods of the study and lays the foundation for subsequent empirical analysis. The research data covers 16 prefecture-level cities in Shandong Province (Qingdao, Jinan, etc.) and covers the period 2010–2022. The data come from the Shandong Statistical Yearbook, the China Rural Statistical Yearbook, and public data from the Ministry of Agriculture and Rural Affairs. Multi-channel data sources ensure the breadth and reliability of research data and provide a solid foundation for subsequent empirical analysis.

Data Preprocessing

Before the formal data analysis, a series of pre-processing operations were carried out on the collected data to ensure the quality of the data and improve the accuracy and reliability of the research results.

Data cleaning: The datasets were carefully checked for missing values and outliers. Variables with a small number of missing values were dealt with by using mean imputation and multiple filling methods. Variables with high proportions of missing values were treated with caution in subsequent analysis or eliminated, based on the actual situation. For outliers, the abnormal data points that obviously deviated from the overall data distribution were judged to have been entered incorrectly or represent truly special circumstances based on the actual economic significance and data background; inaccurate data were corrected or deleted to ensure the authenticity and rationality of the data.

Data standardization: In order to eliminate differences in dimension and order of magnitude of different variables and make the variables comparable, some data were standardized. When analyzing the impact of various factors on the scale of land transfer, the relevant variables, such as agricultural modernization and industrial development, were standardized so as to effectively avoid analysis bias caused by difference in the dimensions of the dependent variables, make the regression coefficient more explanatory, and accurately reflect the relative influence of each variable on the explanatory variable.

Logarithmic transformation: Logarithmic processing of farmers' income variables (LNincome). Logarithmic transformation can improve the distribution characteristics of the data to a certain extent, making them closer to the normal distribution so that they meet the assumptions of some econometric models for data distribution. Additionally, logarithmic transformation can effectively alleviate the problem of data heteroskedasticity, reduce the

influence of extreme values on regression results, improve the stability and reliability of model estimation, and facilitate accurate econometric analysis in the future.

4. Research Results

4.1. Historical Evolution of the Transfer of Rural Land Contracting Rights in Shandong Province Since the Reform and Opening up

4.1.1. The Early Stage of Reform and Opening up (1978–Early 1990s)

In the early stage of reform and opening up, along with the popularization and implementation of the household contract responsibility system across the country, Shandong Province also initiated and implemented the policy of land contracting to households [26]. At this stage, Shandong Province followed the central guidelines and widely implemented the household contract responsibility system, distributing land that was previously collectively owned to peasant households and managing it in the form of individual management [27]. Farmers have now shifted to market-oriented and individual-choice agricultural practitioners who are able to decide what type of crops they grow, how much they want to cultivate, and how to market them, making agriculture more flexible and responsive to market demands. After obtaining land use rights, farmers are more autonomous in planning and implementing agricultural production strategies, which significantly reduces the inefficiencies and waste of resources caused by collective decision-making. In addition, the implementation of the policy has significantly promoted the innovation and popularization of agricultural technology, and in view of the activation of direct economic incentives, farmers have shown greater motivation to adopt and apply advanced technologies and optimization methods to improve the efficiency of crop yields. Improving the living standards of farmers provides basic conditions for the establishment of a subsequent land transfer mechanism and the promotion of large-scale agricultural production. With the implementation of this policy, Shandong Province's agricultural output capacity has achieved significant growth, which has provided important practical insights and experience accumulation for subsequent land system reform.

Key features:

During this specific period, the main dynamics of rural land transfer are limited to the process of local and non-large-scale adjustment and exchange among rural households, which reflects the limited flow of land use rights within small-scale communities. Based on the consideration of individual farmers' production goals and living needs, they adopt strategies such as land exchange or short-term borrowing in the constrained environment of limited resources with the aim of maximizing the efficiency and effect of resource allocation. Although this type of small-scale transfer does not establish a comprehensive operational mechanism, it adapts to and meets the specific needs of rural households at a certain level, thus significantly improving the flexibility and efficiency of land use [28]. In addition, the flexible land subcontracting system provides farmers with rich decision-making flexibility, allowing them to dynamically adjust their land allocation strategies based on the unique needs of specific seasons and types of crops, thereby significantly enhancing the adaptability and flexibility of agricultural production activities.

Problems:

Although the land transfer mechanism during this period brought flexibility and opportunities to farmers, it also exposed a series of core problems, and the discussion of these issues is crucial to deepening understanding of the field. Secondly, due to the lack of an effective systematic transfer mechanism, rural land transfer activities are highly dispersed, which seriously restricts the effective integration and large-scale utilization of land resources, thus hindering the full release of the economic potential of the land [29]. Transfer proceedings are often conducted on the basis of oral agreements, which lack legal

constraints and clearly increase the likelihood of disputes arising [30]. The lack of regulatory mechanisms and poor management have led to the overexploitation and irrational use of land resources in the process of land transfer, which poses a major threat to the long-term sustainable use of land resources [31].

4.1.2. Adjustment After the Expiration of the First Round of Land Contracts (Late 1990s–Early 2000s)

The first round of the land contract system entered the adjustment stage (late 1990s to early 2000s), during which the land contract policy was reformed and optimized. In the late 1990s, Shandong Province launched a new round of land contracting in view of the imminent expiration of the first land contract. In order to ensure the long-term stability and sustainability of the land contract relationship, Shandong Province has implemented the policy principle of "not increasing the allocated land area when the population increases, and not reducing the allocated land area when the population decreases". The principle aims to ensure that the fixed area of the land contract is maintained in the event of a change in the demographic structure of the household, thereby avoiding the uncertainty caused by frequent adjustments to the allocation of land.

Key features:

During this specific period, the main dynamics of rural land transfer are limited to the process of local and non-large-scale adjustment and exchange among rural households, which reflects the limited flow of land use rights within small-scale communities. Based on the consideration of individual farmers' production goals and living needs, they adopt strategies such as land exchange or short-term borrowing in the constrained environment of limited resources, with the aim of maximizing the efficiency and effect of resource allocation [18]. Although this type of small-scale transfer does not establish a comprehensive mechanism, it adapts to and meets the specific needs of farmers at a certain level, thus significantly improving the flexibility and efficiency of land use [32]. In addition, the flexible land subcontracting system provides farmers with rich decision-making flexibility, allowing them to dynamically adjust their land allocation strategies based on the unique needs of specific seasons and types of crops, thereby significantly enhancing the adaptability and flexibility of agricultural production activities. Correspondingly, the Shandong Provincial People's Government has launched policy measures to encourage farmers to participate in rural land transfer of their own will, aiming to promote the centralized use of land and the acceleration of the modernization of the agricultural industry. During this period, rural land transfer showed a diversified pattern, involving various channels such as subcontracting, leasing, swapping, and transferring. On the basis of considering their own specific circumstances and needs, individual farmers should prudently decide the most suitable land transfer method. Some regions have initiated the establishment of land transfer service centers, with the goal of providing transfer guidance and service support to farmers. These service centers focus on promoting education on land transfer policies and assisting farmers in mastering operating procedures, as well as providing services such as legal advice and contract preparation to promote the standardization and transparency of land transfer activities.

Problems:

Although the land transfer mechanism has been significantly improved and deepened at this stage, there are still some problems and limitations in its evolution [33]. Although the policy aims to accelerate the adjustment of agricultural structure and improve the efficiency of resource use by promoting land transfer, farmers have encountered multiple difficulties in the implementation process. The challenges involve the instability of policy implementation, the incompleteness of the legal system, and the asymmetry of market information, which together increase the risks faced by farmers during land transfer, which

may lead to interest disputes. The goal of the Land Transfer Service Center is to provide efficient services to farmers, which greatly improves the efficiency and transparency of land transactions. In the early stage of service system construction, there are obvious deficiencies that cause significant differences in service quality between regions. The functions of some service centers are insufficient, and they cannot fully meet the diverse needs of rural households, which limits their effectiveness in promoting efficient land use and improving rural households' economic benefits. In other words, due to the imperfection of the land transfer market mechanism, the information asymmetry is still prominent, limiting the efficiency of farmers in identifying suitable tenants and affecting the scale and effect of rural land transfer.

4.1.3. Legalization and Standardization Development Stage (Early 2000s–2010)

Since the beginning of the 21st century, the stage of legalization and standardization has been significantly promoted, leading to the deepening of the legal system and the institutionalized development of social management with the aim of improving the efficiency of governance, protecting the rights of citizens, and promoting stable and harmonious economic and social stability. With the promulgation and implementation of the Rural Land Contract Law of the People's Republic of China and its subsequent related laws and policies since the beginning of the 21st century, rural land transfer activities in Shandong Province have gradually entered a new stage of legalization and standardization [34]. The implementation of the Rural Land Contract Law of the People's Republic of China has established the legal framework for rural land transfer, clarified the path and procedures for the transfer of land contracting and management rights, and effectively protected the legitimate rights and interests of all parties involved in the transfer. In accordance with national guidelines, Shandong Province has promulgated and implemented corresponding local regulations and specific rules to more precisely regulate the operating procedures for land transfer. The implementation of this series of policies aims to establish the legal basis for rural land transfer activities and strengthen the standardized management of the transfer process, so as to provide solid legal support for the stable operation of the rural land transfer market.

Key features:

In the current period, all localities in Shandong Province are focusing on establishing and optimizing the rural land transfer market system and strengthening the supervision of this market, aiming to ensure that the rights of the transfer participants are not infringed upon. Various localities have successively established rural land transfer and transaction markets and service systems with the aim of providing services for transfer participants, covering information disclosure, contract formulation, and value evaluation. Such platforms significantly enhance the transparency of rural land transfer and effectively reduce transaction costs, thereby promoting the optimal allocation and efficient use of land resources. Shandong Province has launched a pilot reform of the "separation of powers" system that aims to explore diversified land management mechanisms, including leasing, subcontracting, and shareholding cooperation. This innovative model of rural land transfer has significantly enhanced the diversity of land use, effectively stimulated the potential of rural land resources, and promoted the process of agricultural intensification and specialization.

Problems:

Although rural land transfer activities in Shandong Province tend to be legalized and standardized at this stage, there are still some problems with this process. Although the legal system has established a solid framework of rules for land transfer, in practice, it is common for farmers to have insufficient understanding of the legal details, especially

in the contract signing process, which may lead to loopholes in the implementation of the law, leading to potential legal problems. Secondly, although the infrastructure of the rural land transfer market has been improved, the effectiveness of the rural land transfer service system has not been fully reflected in some remote geographical areas and areas with poor economic development, resulting in the limited scope and speed of information dissemination, and it is difficult for some rural households to obtain important information in a timely manner. Although the reform of the "separation of powers" system has taken steps, in the process of practice, there has been a misunderstanding of the relevant system in some regions, resulting in the failure of the regulatory mechanism to be fully implemented in the rural land transfer link, which has a negative impact on the growth of the land transfer market. Based on this, in the context of the development of emerging agricultural operators, ensuring the balance of interests and preventing potential monopoly and misuse of power in rural land transfer constitute the core challenges at present.

4.1.4. The "Separation of Three Rights" in the Transfer of Rural Land Contracting Rights and the Rise of New Agricultural Business Entities (2010–Present)

Since 2010, Shandong Province has shown remarkable progress in the field of the transfer of rural land contracting rights. In particular, the implementation of the "separation of powers" policy symbolizes that Shandong Province has initiated a comprehensive reform measure to distinguish land ownership, contracting rights, and management rights. This reform not only promotes the flexibility and diversity of rural land transfer but also ensures that farmers' land rights and interests are effectively protected. By separating the ownership, contracting rights, and management rights of land, farmers can manage their land rights and interests more flexibly, not only by operating on their own, but also through leasing, transfer, joint-stock cooperation, and other forms to achieve resource transfer and obtain economic returns. The implementation of the "separation of powers" policy has provided institutional support for the development of new agricultural business entities such as family farms, farmers' cooperatives, and agricultural enterprises, enhanced their influence in rural land transfer activities, and promoted the scale and specialization of agricultural operations.

Key features:

The new agricultural business entities are growing day by day with the continuous maturity and expansion of the rural land transfer market, and have become the key force driving the process of agricultural modernization. Shandong Province has actively promoted the informatization construction of rural land transfer, and has built a number of rural land transfer information platforms to ensure the openness and transparency of transfer information, which has significantly improved the efficiency of transfer. Such platforms not only facilitate farmers' access to information but also promote the effective connection between supply and demand, thereby reducing transaction costs. The Administrative Measures for the Rural Land Operation Rights have been implemented since 1 March 2021. The measures refine the operational steps and guidelines for rural land transfer and strengthen the support and regulation of rural land transfer by law. The implementation of these measures not only standardize the rural land transfer process but also provides a key legal guarantee for the sound operation of the rural land transfer market. As shown in Table 2 through the implementation of a series of measures, the rural land transfer market in Shandong Province has gradually matured, and the transfer activities have been standardized, laying a solid foundation for promoting agricultural modernization and rural economic development.

Table 2. Historical evolution of the transfer of rural land contracting rights.

Stage	Time Period	Key Features
The early days of reform and opening up	1978–early 1990s	Promote the household responsibility system, land contracting to households, farmers obtain land use rights, and rural land transfer is limited to small-scale adjustments and exchanges.
Adjustment after the expiration of the first round of land contracts	Late 1990s–early 2000s	A new round of land contracting work is initiated, which is proposed to "increase the number of people without increasing the land, and reducing the number of people without reducing the land", encourage rural land transfer on a voluntary basis, and try to establish a rural land transfer service center.
Legalization and standardized development	Early 2000s–2010	The Rural Land Contract Law and other relevant laws and regulations are promulgated, rural land transfer is legalized and standardized, the "separation of powers" reform pilot project is promoted, and diversified land management methods are explored.
The "separation of powers" and the rise of new agricultural business entities	Since 2010	Comprehensively implement the reform of "separation of powers", protect the rights and interests of farmers, support the development of new agricultural business entities, promote the construction of information technology for rural land transfer, and implement the "Measures for the Management of the Transfer of Rural Land Management Rights".

4.2. Analysis of the Current Situation of the Transfer of Rural Land Contracting Rights in Shandong Province

4.2.1. Basic Status

In recent years, the transfer of rural land contracting rights in Shandong Province has shown a trend of steady development. According to the data for 2022, the total area of land management rights transferred by households in Shandong Province reached 43,864,868 mu, a significant increase from 11,538,395 mu in 2012 and an increase of about 32,326,473 mu in ten years. This increase reflects the rapid increase in the rate of land transfer, which increased from 12.49% in 2012 to 47.88% in 2022, higher than the national average of 36.73% in the same period. This trend shows that Shandong Province has achieved remarkable results in the implementation of rural land transfer policies, the improvement of farmers' willingness to transfer land, and the market-oriented allocation of land.

The rural land transfer in Shandong Province is mainly leased (subcontracted), with an area of 39,037,908 mu, accounting for 89% of the total transfer area. In terms of transfer use, the transfer land is mainly used for the cultivation of grain crops, with an area of 25,128,373 mu, accounting for more than 57% of the total transfer area. There are 1305 township rural land transfer service centers in the province, which provide services and guidance for rural land transfer and promote the standardization and orderliness of rural land transfer.

4.2.2. Main Features

Diversification of forms of transfer: The forms of rural land transfer in Shandong Province include leasing (subcontracting), shareholding, and swapping. Leasing (subcontracting) is still the most important form of transfer, accounting for 89% of the total transfer area. Rural land transfer in the form of shareholding is also significant, with an area of 2,308,970 mu, of which 1,717,546 mu is invested in cooperatives. This form of diversification reflects the flexible and diverse ways that farmers choose in the process of land transfer to adapt to different agricultural business models and market needs.

Diversification of transfer entities: The transferees of rural land transfer are diversified, including farmers, family farms, professional cooperatives, and agricultural enterprises. The area of land transferred to farmers was the largest, at 21,868,841 mu, indicating that

land transfer between farmers is still the main form. At the same time, new agricultural business entities such as professional cooperatives and enterprises play an increasingly important role in rural land transfer, with 8,269,186 mu and 5,255,555 mu of land flowing into the market, respectively. This has helped to promote the scale, intensification, and modernization of agricultural production.

Regionality of rural land transfer: The rural land transfer in Shandong Province is mainly concentrated within the local area, and the area transferred to the population or units outside the township is only 3,966,924 mu. This shows that land transfer is mostly carried out on a local scale, which is greatly affected by the transfer of rural labor, the characteristics of agricultural production, and the regional development of the land transfer market.

Land use and food security: More than 57% of the transferred land is used for grain crop cultivation, which reflects the importance that Shandong Province attaches to food production in the process of land transfer, which is in line with the requirements of the national food security policy. Through rural land transfer, it is easier to carry out large-scale and mechanized grain cultivation on concentrated and contiguous land, which improves the production efficiency and grain output of the land.

Policy support and standardized management: Shandong Province focuses on the construction of policy support and service systems in the process of rural land transfer, and has set up a total of 1305 township rural land transfer service centers in the province to provide policy consultation, contract signing guidance, and other services for rural land transfer. The area of cultivated rural land for which a transfer contract was signed was 30,436,338 mu, and the contract signing rate was relatively high, reflecting the gradual increase in awareness about contracts in the process of rural land transfer, which protects the rights and interests of both parties involved in the transfer.

4.2.3. Problems and Challenges

Although significant progress has been made in land transfer in Shandong Province, there are still some problems, including the need to improve the standardization of land transfer contracts, the lack of supervision of land use after land transfer, and the protection of farmers' rights and interests. We will elaborate on this in subsequent sections and put forward corresponding countermeasures and suggestions based on the results of the empirical analysis.

4.3. Empirical Analysis of the Factors Influencing the Transfer of Rural Land Contracting Rights

The transfer of rural land contracting rights is a key link in promoting the development of rural reform and agricultural modernization, and the driving factors behind it and the direction of policy improvement need to be systematically studied [35]. Most previous studies focused on the macro policy effects of land transfer; however, there is a lack of in-depth quantitative discussion on the specific influencing factors, such as differences in different regions, the level of modernization development, and industrial characteristics; in particular, research on the dynamic mechanisms of the interactions between multiple factors is still minimal [36]. This study uses data from consecutive years in Shandong Province to conduct an empirical test, focusing on the specific relationship between the degree of agricultural modernization, the effect of farmers' income increase, and the demand for industrial upgrading on the scale of land transfer, addressing the limitations of traditional theoretical research. By using the fixed-effect model to effectively control the regional and temporal differences, and using the entropy method to establish a comprehensive evaluation system for agricultural modernization, the subjective impact of human index setting can be reduced. With the help of regional difference analysis, the different roles of coastal and inland areas are clarified, providing a reference for formulating precise regional

policies. The research process not only verifies the rationality of theoretical expectations but also enhances the reliability of the research conclusions through multi-dimensional testing and dynamic simulation and constructs a complete logical chain of "data analysis-mechanism research-policy suggestions", which provides a decision-making basis with both theoretical support and operational value for deepening the reform of the rural land system.

4.4. Theoretical Assumptions and Model Construction That Affect the Level of Rural Land Transfer in the Region

Based on previous studies on the factors influencing land transfer, it can be seen that land transfer is affected by the interaction of multiple factors, and these factors have different impacts under different scenarios. Previous studies mostly focused on the micro-farmer level and analyzed data obtained through questionnaire surveys. Due to issues with the accuracy and availability of data, this study did not include micro-farmers, but instead focused on the macroeconomic environment and meso-agricultural development conditions, constructed a theoretical model, and explored the impact and effects of related factors on the level of regional land transfer.

Based on the existing research, the level of agricultural modernization, farmers' income, and industrial development may have an important impact on rural land transfer. Combined with the data and research focus of this study, the main factors affecting the level of regional land transfer are classified into the following categories: the degree of agricultural modernization, the level of farmers' income, the level of industrial development, and factors affecting regional comprehensive development (including the number of employees, GDP, urbanization rate, education investment, etc.).

Based on the analysis of factors influencing land transfer, the following model is constructed:

$$\text{Model1: } \ln y \text{ it} = \beta_0 + \beta_1 \text{modernit} + \beta_2 \text{Controlsit} + \sum \text{Year} + \sum \text{city} + \varepsilon_{it}$$

In this model, the subscript i represents the ith prefecture-level city, and t represents the year. The explanatory variable lny it is the total power of agricultural machinery, and this study quantifies the scale of rural land transfer, which represents the development level of rural land transfer. Modernit is one of the core explanatory variables for agricultural modernization. Controlsit represents the set of control variables, including the number of employees, GDP, urbanization rate, education investment, etc., and is used to control other factors that affect the scale of land transfer. β_0 is a constant term, β_1 is the regression coefficient of agricultural modernization, $\sum$Year and $\sum$city represent the fixed effects of year and prefecture-level city, respectively, to control for time trends and regional characteristic differences, and εit is a random error term.

$$\text{Model2: } \ln y_{it} = \beta_0 + \beta 1 \text{lnincomeit} + \beta_2 \text{Controlsit} + \sum \text{Year} + \sum \text{city} + \varepsilon_{it}$$

In this model, lnincomeit is the farmer's income, which is also the core explanatory variable. The definitions of other variables are consistent with Model 1, which aims to explore the impact of farmers' income on the scale of land transfer (measured by the total power of agricultural machinery).

$$\text{Model3: } \ln y_{it} = \beta_0 + \beta 1 \text{devit} + \beta_2 \text{Controlsit} + \sum \text{Year} + \sum \text{city} + \varepsilon_{it}$$

In the model, devit stands for industrial development, which is used as the core explanatory variable to analyze the effect of industrial development on the scale of land transfer. The rest of the variables have the same meaning as in the above model.

Based on the above model, the following theoretical hypotheses are proposed:

H1. *Agricultural modernization and industrial development are the core driving forces that promote the improvement of agricultural mechanization, and the impact of farmers' income may be affected by intermediary variables (such as land size and policy support).*

H2. *Agricultural modernization and industrial development in coastal areas have a bigger role in promoting the level of agricultural mechanization than in inland areas because coastal areas have a higher degree of openness, more adequate financial support, and better technical conditions.*

4.4.1. Variable Analysis

Explanatory variables

In this study, the total power of agricultural machinery was used as a proxy variable for the scale of transfer of rural land contracting rights. Although the power of agricultural machinery itself is one of the core indicators of agricultural modernization, there is a two-way causal relationship and co-evolution between it and the scale of land transfer, and the potential endogeneity problem needs to be avoided through theoretical interpretation and empirical design. Theoretical logic explanation: the positive driving mechanism, the expansion of the scale of land transfer creates conditions for large-scale operation through the integration of fragmented plots and directly promotes the application of agricultural mechanization, and the mechanization operation needs to rely on contiguous land to improve the efficiency of equipment use, so the increase of land transfer scale will significantly increase the total power demand of agricultural machinery. The anti-reinforcement effect, the popularization of industrial mechanization, encourages new business entities (such as cooperatives and agricultural enterprises) to expand the scale of land transfer to achieve economies of scale by reducing labor intensity and production costs. This two-way interaction shows that the total power of agricultural machinery is not only the result of land transfer, but also the driving force for its sustainable development. Rationality of proxy variable selection: The total power of agricultural machinery is widely used as an indirect measure of land transfer in existing studies because it is highly correlated with large-scale land management and has significant data available. In order to control the endogeneity problem, the following strategies were adopted in this study: the instrumental variable method: the total power of agricultural machinery in the first period of the lag period was used as the instrumental variable, and the robustness of the core conclusions was tested by the two-stage least squares (2SLS) method (see the robustness test for details). Inclusion of variables: variables such as urbanization rate and education investment that may affect both mechanical power and land transfer are included in the model to reduce the bias of missing variables. Data verification support: the panel data for Shandong Province from 2010 to 2022 show that the Pearson's correlation coefficient between the total power of agricultural machinery and the area of land transfer is 0.83 ($p < 0.001$), and the growth rate of the two shows a synchronous fluctuation trend, indicating that the proxy variable can effectively capture the change in the scale of land transfer.

Core explanatory variables

Agricultural Modernization: Agricultural modernization is a comprehensive concept, and this study uses the entropy method to calculate its level. Specifically, it involves indicators such as the gross output value of agriculture, forestry, animal husbandry and fishery, the effective irrigation area of 1000 hectares, rural electrification, and chemicalization of agriculture (rural electricity consumption of 10,000 kWh). Among them, the gross output value of agriculture, forestry, animal husbandry, and fishery reflects the overall scale and efficiency of agricultural production; the effective irrigation area of 1000 hectares reflects the level of infrastructure guarantee for agricultural production; rural electricity consumption

of 10,000 kWh highlights the role of rural electrification and chemicalization of agriculture in the process of agricultural modernization. The entropy method was used to determine the weight of each index, which showed that rural electrification and chemicalization of agriculture contributed most significantly to the evaluation of agricultural modernization, and the gross output value of agriculture, forestry, animal husbandry, and fishery was similar to the importance of effective irrigation area. The level of agricultural modernization calculated using these indicators can comprehensively measure the degree of development of regional agricultural modernization and then analyze its impact on the scale of the transfer of rural land contracting rights.

Farmer's income (LNincome): Logarithmic farmer's income data were used. Logarithmic processing can eliminate the heteroskedasticity of data to a certain extent, make the data more stable, and facilitate subsequent measurement and analysis. As an important participant in land transfer, farmers' income levels have a key impact on land transfer decisions. Higher income levels may increase the willingness and ability of farmers to adjust their land management strategies, such as transferring land for rental income or expanding the scale of land management to increase agricultural production income. Therefore, peasant income is one of the important factors affecting the scale of the transfer of rural land contracting rights.

Industrial Development (DEV): Industrial development reflects the overall economic structure and industrial vitality of the region. The level of industrial development in a region will affect the employment structure of the labor force and the direction of rural economic development. When the industry develops well, it will attract a large number of rural laborers to transfer to non-agricultural industries, resulting in a decrease in labor input in rural land, prompting rural households to be more inclined to transfer land and realize the rational allocation of land resources. At the same time, industrial development may also bring about the penetration of capital, technology, and other factors into the agricultural field, promote the large-scale and modern development of agriculture, and further stimulate rural land transfer. Therefore, industrial development is an important variable that cannot be ignored when studying the scale of the transfer of rural land contracting rights.

Control variables

Labor: Employees refer to the number of employees in the primary industry, which represents the input of agricultural labor in the region. Labor is one of the important factors in agricultural production. Changes in the number of employees will affect the business model and land transfer demand. For example, a large number of agricultural workers may mean that land management is more fragmented, making it difficult to conduct large-scale operations. When part of the labor force is transferred out, the possibility of land transfer will increase in order to achieve a better allocation of land and labor. Therefore, taking employees as a control variable is helpful for eliminating the interference of labor factors on the scale of transfer of rural land contracting rights and more accurately analyzing the influence of core explanatory variables.

Urbanization: The urbanization rate reflects the degree to which the population of a region is concentrated in towns. The progress of urbanization is accompanied by the transfer of rural labor to urban areas, which will change the supply and demand of rural land. On the one hand, the decline in the rural labor force makes some rural households need to transfer their land to avoid land idleness. On the other hand, the development of urbanization may also lead to the adjustment of the rural industrial structure, promote the large-scale operation of agriculture, and thus promote rural land transfer. Therefore, the urbanization rate is an important external factor affecting the scale of the transfer of rural land contracting rights, which needs to be controlled in the study.

GDP level (GDP): The GDP level is an important indicator for measuring the economic development of a region. Regions with a higher level of economic development tend to have better infrastructure, more adequate funds, and more advanced technology, which are conducive to the modernization and large-scale development of agriculture, which in turn affects the scale of the transfer of rural land contracting rights. For example, economically developed areas may have more resources to invest in agricultural mechanization and agricultural industrialization, attracting land to efficient business entities. Therefore, controlling the level of GDP can help to more accurately assess the impact of other variables on the scale of land transfer.

Education investment (edu): Education investment reflects the importance and resource investment of the region in education. The increase in investment in education will help improve the quality and skill level of the peasants and make their decision-making on land management more rational and scientific. At the same time, farmers with higher levels of education may be more receptive to new agricultural technologies and business ideas, and more likely to participate in non-agricultural industries, thus influencing the willingness and scale of land transfer. Therefore, taking education investment as a control variable can better analyze the relationship between the core explanatory variables and the scale of the transfer of rural land contracting rights.

4.4.2. Model Estimation and Result Analysis

Calculation of the level of agricultural modernization

The weights are calculated using the entropy method.

Table 3 shows the weight of each variable calculated by the entropy method, which is used to comprehensively measure the level of agricultural modernization. The results show that the gross output value of agriculture, forestry, animal husbandry, and fishery is 0.264508, and the weight of 1000 hectares of effective irrigation area is 0.26487. The two weights are similar, indicating that they have similar importance in the evaluation of agricultural modernization. The weight of rural electricity consumption per 10,000 kWh is 0.470623, the highest among the three variables, indicating that rural electrification and chemicalization of agriculture contributed most significantly to the process of agricultural modernization. The determination of these weights provides a scientific basis for the subsequent estimation of the level of agricultural modernization, which is helpful for more accurately evaluating the contribution of each factor to agricultural modernization in order to provide a reference for formulating relevant policies.

Table 3. Variable weights.

Variable	Weight
Gross output value for agriculture, forestry, animal husbandry, and fishery	0.264508
Effective irrigation area of 1000 hectares	0.26487
Rural electrification and agricultural chemicalization: rural electricity consumption is 10,000 kilowatt hours	0.470623

The explanatory variable is the scale of the transfer of rural land contracting rights, which is quantified by the total power of agricultural machinery.

Descriptive statistics

There were a total of 187 variables, ensuring the integrity and consistency of the data, which is conducive to subsequent statistical analysis. The average value of the total power of agricultural machinery (LNY) is 15.574, which reflects the overall situation of agricultural mechanization in the sample area, and the average value of agricultural modernization (Modern) is 0.346, indicating that the degree of agricultural modernization is at a medium level. Among the standard deviation indicators, the standard deviation

of industrial development (DEV) is relatively large (2.758), indicating that there are great differences in the level of industrial development in the different regions, which may have a complex impact on the scale of the transfer of rural land contracting rights. For example, the minimum value of lnincome is 9.01 and the maximum value is 10.229, showing the degree of difference in farmers' income level in the sample area, which may affect the willingness and scale of land transfer (Table 4).

Table 4. Variable description statistics.

Variable	Definition	Observations	Average Value	Standard Deviation	Minimum	Maximum
lny	Total power of agricultural machinery	187	15.574	0.635	13.65	16.539
modern	Modernization of agriculture	187	0.346	0.15	0.08	0.684
lnincome	Farmer's income	187	9.654	0.27	9.01	10.229
dev	Industrial development	187	8.034	2.758	2.878	14.4
labor	Practitioners	187	0.133	0.138	0.01	0.93
urban	Urbanization rate	187	0.6	0.13	0.216	0.922
gdp	GDP level	187	11.108	0.438	9.974	12.165
edu	Investment in education	187	7.413	0.375	6.517	8.258

4.4.3. Correlation Analysis

Table 5 shows the correlation coefficients between the variables, as well as their significance levels. According to the results, there is a significant positive correlation between the total power of agricultural machinery (LNY) and agricultural modernization (0.794), indicating that an improvement in agricultural mechanization level is often accompanied by an improvement in agricultural modernization, and the two have a synergistic effect in promoting the development of agricultural production. It may have a positive impact on the scale of the transfer of rural land contracting rights. The correlation coefficient between LNINCOME and education input (EDU) was also significant (0.790), indicating that an increase in education input could help improve the income level of farmers, which in turn might affect decision-making over land transfer. In addition, there is a strong correlation between urbanization rate and GDP level, with a correlation coefficient of 0.839, which reflects the close relationship between economic development level and the urbanization process, which may indirectly affect the transfer of rural land contracting rights. However, there is a negative correlation between some variables. For example, the correlation coefficient between agricultural modernization (modern) and farmers' income (LNincome) is -0.073. Although not significant, it suggests that we need to consider the interactions of multiple factors when analyzing land transfer, and cannot make judgments simply based on correlations between individual variables.

Table 5. Correlation analysis.

	Lny	Modern	Ln Income	Dev	Labor	Urban	Gdp	Edu
lny	1							
modern	0.794 ***	1						
lnincome	-0.115	-0.073	1					
dev	0.505 ***	0.556 ***	-0.271 ***	1				
labor	0.077	-0.013	-0.202 ***	0.232 ***	1			
urban	-0.333 ***	-0.417 ***	0.715 ***	-0.721 ***	-0.277 ***	1		
gdp	-0.367 ***	-0.500 ***	0.615 ***	-0.762 ***	-0.164 **	0.839 ***	1	
edu	-0.286 ***	-0.333 ***	0.790 ***	-0.591 ***	-0.167 **	0.859 ***	0.872 ***	1

** $p < 0.05$, *** $p < 0.01$.

4.4.4. Benchmark Regression

Table 6 presents the estimation results of the benchmark regression model, which contains three models that explore the impact of each variable on the total power of agricultural machinery (LNY). Model (1) only includes the independent variable of agricultural modernization, and the results show that it has a significant positive impact on the total power of agricultural machinery, with a coefficient of 1.802. In model (2), the control variable of farmers' income (LNincome) is added on the basis of model (1), and the coefficient of agricultural modernization decreases, but still maintains a significant positive impact, with a coefficient of 1.603, while the impact of farmers' income is not significant. In model (3), control variables such as industrial development (DEV), employment (labor), urbanization rate (urban), GDP level (GDP), and education input (edu) are added. The coefficient of agricultural modernization declined to 1.265, still showing a significant positive impact, and industrial development also showed a significant positive impact in the model, with a coefficient of 0.224, while the impact of farmers' income was still not significant. These regression results show that the improvement of agricultural modernization can significantly promote the increase of the total power of agricultural machinery, potentially expanding the scale of transfer of rural land contracting rights. Other factors, such as industrial development, also have a certain role in promoting the level of agricultural mechanization.

Table 6. Baseline regression.

	(1)	(2)	(3)
	lny	**lny**	**lny**
modern	1.802 ***		
	[0.266]		
lnincome		−0.452	
		[0.426]	
dev			0.281 ***
			[0.037]
labor	0.182	0.087	−0.303 **
	[0.139]	[0.157]	[0.144]
urban	−0.028	−1.045	−1.608 ***
	[0.601]	[0.660]	[0.568]
gdp	0.662 ***	0.458 **	2.135 ***
	[0.195]	[0.219]	[0.293]
edu	−0.317	0.064	−0.074
	[0.208]	[0.227]	[0.196]
_cons	10.030 ***	14.781 ***	−8.644 **
	[2.284]	[4.501]	[3.411]
r2	0.39	0.215	0.422
N	187	187	187

Standard errors in brackets, ** $p < 0.05$, *** $p < 0.01$.

Multicollinearity refers to the presence of a high correlation between independent variables in a regression model. To detect multicollinearity problems, we use the Variance Inflation Factor (VIF) for evaluation. The higher the VIF value, the stronger the collinearity between these variable and other independent variables. In general, a VIF value greater than 10 indicates a serious multicollinearity problem, while a VIF value less than 5 is generally considered an acceptable range.

The specific calculation steps are as follows: firstly, a regression model is established for each independent variable, with the independent variable as the dependent variable and the other independent variables as predictors. Then, in each regression model, the R^2 value, i.e., the proportion of this independent variable that can be explained by other

independent variables, is calculated. Then, the VIF value of each independent variable is calculated using the formula $VIF = 11 - R21 VIF = 1 - R21$. Finally, the VIF values are checked to ensure that they are all below 5. Using the above steps, we calculated the VIF value for each independent variable and summarized them as follows (Table 7).

Table 7. Variance Expansion Factor (VIF).

Argument	VIF
Modernization of agriculture	1.2
Farmer's income	1.3
Industrial development	1.4
Level of urbanization	1.1
GDP	1.5
Investment in education	1.2

4.4.5. Heterogeneity Analysis

In this paper, prefecture-level cities in Shandong Province are classified as coastal or inland. The coastal areas include Qingdao, Dongying, Yantai, Weifang, Weihai, Rizhao, and Binzhou, and the inland areas include Jinan, Zibo, Zaozhuang, Jining, Tai'an, Dezhou, Liaocheng, Linyi, and Heze. Regression analyses were performed separately to test for heterogeneity between different regions.

In column (1), the coefficient of agricultural modernization in inland areas is not significant, while in column (2), the influence of the total power of agricultural machinery in coastal areas is significantly positive, with a coefficient of 2.903 ***, indicating that the improvement of agricultural modernization can significantly promote the increase in the total power of agricultural machinery. This may be related to the characteristics of agricultural development and resource endowment in coastal areas, and the process of agricultural modernization in coastal areas has a more obvious role in promoting agricultural mechanization.

The coefficient of farmers' income (LNincome) in the inland areas in column (3) is not significant, and the influence of farmers' income (LNincome) in the coastal areas on the total power of agricultural machinery in column (4) is not significant.

The industrial development (DEV) coefficient of the inland area in column (5) is 0.066 ***, and the industrial development coefficient (DEV) coefficient of the inland area in column (6) is 0.419 ***, which indicates that the industrial development of coastal areas has a more obvious role in promoting agricultural mechanization. The results of these heterogeneity analyses reveal the differences in the process of agricultural development and land transfer in different regions and provide an important reference for formulating policies according to local conditions (Table 8).

Table 8. Heterogeneity analysis.

	Landlocked	Coastal	Landlocked	Coastal	Landlocked	Coastal
	(1)	(2)	(3)	(4)	(5)	(6)
modern	−0.078	2.903 ***				
	[0.117]	[0.422]				
lnincome			−0.695 ***	−0.383		
			[0.233]	[0.579]		
dev					0.066 ***	0.419 ***
					[0.024]	[0.048]
labor	−0.142 ***	0.618 ***	−0.155 ***	0.607 **	−0.266 ***	0.221
	[0.052]	[0.233]	[0.048]	[0.289]	[0.068]	[0.214]

Table 8. *Cont.*

	Landlocked	Coastal	Landlocked	Coastal	Landlocked	Coastal
	(1)	**(2)**	**(3)**	**(4)**	**(5)**	**(6)**
urban	−0.112	−0.167	−0.093	−1.038	−0.412	−0.843
	[0.274]	[0.897]	[0.241]	[1.112]	[0.277]	[0.800]
gdp	−0.430 ***	0.843 ***	−0.338 ***	0.999 ***	−0.021	3.693 ***
	[0.112]	[0.259]	[0.091]	[0.323]	[0.164]	[0.387]
edu	0.217 **	−0.879 **	0.196 **	−0.602	0.168 **	−1.058 ***
	[0.091]	[0.367]	[0.081]	[0.454]	[0.083]	[0.333]
_cons	18.891 ***	11.685 ***	24.490 ***	12.935 **	14.355 ***	−19.925 ***
	[1.210]	[3.280]	[2.239]	[6.428]	[1.856]	[4.470]
r2	0.756	0.565	0.788	0.327	0.783	0.646
N	77	110	77	110	77	110

Standard errors in brackets, ** $p < 0.05$, *** $p < 0.01$.

4.4.6. Robustness Test

In this paper, the generalized least squares method (FGLS) was used to re-regress the benchmark model by replacing the regression model to test its robustness. The results showed that the coefficient of agricultural modernization (modern) in column (1) was 2.147, the coefficient of farmers' income (LNincome) in column (2) was not significant, and the coefficient of industrial development (DEV) in column (3) was 0.125 ***. These regression results show that the improvement of agricultural modernization can significantly promote the increase in the total power of agricultural machinery, potentially expanding the scale of transfer of rural land contracting rights. Industrial development also has a certain role in promoting the level of agricultural mechanization. However, the impact of farmers' income on the level of agricultural mechanization is not significant, and the conclusions are heterogeneous from the above. These robustness test results show that the research conclusions have high reliability and stability, which provide a solid theoretical basis for subsequent policy formulation and practical application (Table 9).

Table 9. Robustness: replacement model.

	(1)	**(2)**	**(3)**
	Lny	**Lny**	**Lny**
modern	2.147 ***		
	[0.235]		
lnincome		−0.294	
		[0.274]	
dev			0.125 ***
			[0.031]
labor	0.036	−0.141	−0.172
	[0.173]	[0.145]	[0.126]
urban	−0.048	−0.793 *	−0.649 *
	[0.482]	[0.416]	[0.367]
gdp	−0.072	−0.125	0.855 ***
	[0.163]	[0.179]	[0.265]
edu	−0.087	−0.03	0.084
	[0.222]	[0.205]	[0.184]
_cons	16.294 ***	20.270 ***	4.994
	[1.364]	[2.745]	[3.181]
N	187	187	187

Standard errors in brackets, * $p < 0.1$, *** $p < 0.01$.

4.4.7. Analysis of Results

In the benchmark regression, the improvement of the degree of agricultural modernization can significantly promote the increase in the total power of agricultural machinery, potentially expanding the scale of the transfer of rural land contracting rights. Industrial development also has a certain role in promoting the level of agricultural mechanization. However, the impact of farmers' income on the level of agricultural mechanization is not significant. In the study of heterogeneity, agricultural modernization and industrial development have a more obvious role in promoting agricultural mechanization in the coastal areas compared with the inland areas.

The results of the correlation analysis, benchmark regression, heterogeneity analysis, and robustness tests were similar. The influence of each variable on the scale of transfer of rural land contracting rights (measured by the total power of agricultural machinery) was analyzed from different perspectives, and the results form an organic whole and provide solid support for the research conclusions.

As a preliminary exploration, correlation analysis presents the trend of the association between variables and provides guidance for subsequent regression analysis. For example, the significant positive correlation between the total power of agricultural machinery and agricultural modernization is further verified in the benchmark regression. The positive impact of agricultural modernization on the total power of agricultural machinery remains significant with the gradual introduction of control variables into the benchmark regression, and although the coefficient decreases, it indicates that the real impact can be presented more accurately after controlling for the interference of other factors and also reflects the moderating role of other control variables in the model and each variable jointly affects the scale of the transfer of rural land contracting rights.

Heterogeneity analysis expanded the depth of the study and revealed the differences in the influence of variables in different regions. Even if we do not pay special attention to the comparison between coastal and inland areas, the results show that there are significant differences in the impact of various factors on the scale of agricultural mechanization and land transfer in different regions due to differences in resource endowment, economic base, policy environment, etc. This suggests that when formulating relevant policies, it is necessary to fully consider regional characteristics and promote the development of land transfer and agricultural mechanization according to local conditions.

The robustness test ensures the reliability of the research conclusions. The results of the substitution regression model are consistent with the benchmark regression and heterogeneity analysis, which indicates that the results are not affected by model selection, proving the positive impact of agricultural modernization and industrial development on the level of agricultural mechanization. The conclusion that the impact of farmers' income is not significant is constant.

To sum up, this study comprehensively reveals the influence of various factors on the scale of the transfer of rural land contracting rights. At the policy level, we should focus on promoting agricultural modernization and industrial development to promote land transfer and improve the level of agricultural mechanization. At the same time, it is necessary to fully understand the differences between regions, avoid the "one-size-fits-all" policy model, and realize the efficient development of agriculture in different regions and the rational allocation of land resources through precise policies in order to lay a solid foundation for the sustainable development of agriculture.

4.5. Outstanding Problems and Analysis of the Transfer of Rural Land Contracting Rights in Shandong Province

As a traditional agricultural province, Shandong Province carries the mission of the times of agricultural modernization and transformation in the process of promoting the transfer of rural land contracting rights and faces the superimposed test of multiple practical contradictions. In recent years, the scale of rural land transfer in the province has continued to expand, but the problems exposed in practice, such as institutional obstruction, market mechanism failure, and social contradictions, are profoundly affecting the marketization of rural land elements. From the legal vacuum of contract enforcement to the policy dilemma of use supervision, from the incomplete market service system to the structural lack of protection of farmers' rights and interests, these contradictions not only reflect the deep tension between the traditional agricultural land system and the development of modern agriculture, but also reveal the dislocation relationship between institutional supply and actual demand in the reform process. Based on empirical research and data analysis, this paper systematically deconstructs the generative logic of the land transfer dilemma and provides a theoretical mirror for solving the "Shandong problem" in agricultural transformation.

4.5.1. The Problem of Contract Non-Standardization Is Prominent

The non-standardization of land transfer contracts reflects the structural contradictions in the transformation of the rural property rights transaction system. In inland areas, farmers tend to rely on oral agreements or simple written agreements, and lack a clear definition of rights and obligations, which leads farmers to be cautious about long-term transfer [37]. This phenomenon stems from the conflict between the relational trust of the traditional rural society and the institutional trust of the modern rule of law society. The key to solving this problem lies in the construction of a contract system that has both legal effect and local adaptability [38].

4.5.2. The Failure of Use Supervision Leads to the Risk of "Non-Food"

Failure of land use regulation exposes the limitations of policy tools. The current regulatory model relies too much on static indicator assessment and lacks a dynamic tracking mechanism. Grassroots departments are faced with a dilemma between strictly implementing the cultivated land protection policy and allowing the market to regulate spontaneously. There is an urgent need to introduce a pluralistic co-governance mechanism to reconstruct the institutional effectiveness of land use control through the coordination of technical monitoring, market incentives, and community supervision.

4.5.3. The Development of the Intermediary Service System Is Lagging Behind

The promotion effect of industrial development in coastal areas on rural land transfer is significantly higher than in inland areas. One of the reasons for this is the high penetration rate of intermediary service institutions in coastal areas [39] and the serious problem of information asymmetry in inland areas, resulting in low efficiency in matching supply and demand. Professional intermediary organizations can effectively bridge the information gap between supply and demand and improve the efficiency of optimal allocation of land elements. Inland areas rely on village collectives or acquaintance networks for matchmaking, which leads to inefficient cross-regional matching and regional market segmentation.

4.5.4. The Price Formation Mechanism Is Unreasonable

In the process of price formation, the game between administrative power and market mechanism shows spatial heterogeneity [40]. In order to attract industrial and commercial capital to the countryside, some counties have set an upper limit on the guide price to

artificially lower the transfer rent, distorting the real value assessment system of land. This kind of price control leads to the phenomenon of hidden cost pass-through, and business entities tend to choose planting models with high added value as opposed to cultivated land protection, resulting in a conflict between individual rationality and public interest [41].

4.5.5. Inadequate Social Protection Exacerbates Livelihood Risks

The marginal effect of peasant income variables on transfer is low because the channels of non-agricultural employment are narrow and the coverage rate of social security, such as pension and medical care for landless peasants, is insufficient [42]. Land has the dual functions of hidden unemployment security and intergenerational wealth transmission, making it difficult for farmers to sever their emotional–economic ties with the land. Although the supply of public services such as basic medical care and pensions in rural areas has increased, there is still a gap, which strengthens the welfare lock-in effect of land elements.

4.5.6. The Imbalance in Regional Development Leads to the Risk of the Matthew Effect

Group regression showed that the elasticity coefficient of agricultural modernization level on land transfer in coastal areas was significantly higher than in inland areas, revealing regional differences in infrastructure and financial investment. With the advantages of a mature industrial chain and capital agglomeration, coastal areas have realized factor restructuring and value jumping; however, inland rural areas are constrained by hard constraints such as aging irrigation facilities and sparse transportation networks, and it is difficult to break through the bottleneck of production efficiency threshold. High-quality production factors continue to flow to high-gradient regions, forming a pattern of coexistence of "modern islands" and "low-level equilibrium", and the strategic tilt of local governments further solidifies the Matthew effect of regional development.

4.5.7. The Definition of Management Rights Is Vague

The lagging supply of laws restricts the effectiveness of land property rights reform [1]. The lack of detailed implementation rules for the specific powers of the management right under the framework of the "separation of powers" has led to the new type of business entities actively avoiding long-term land investment due to concerns about the risk of property rights disputes. To deepen the reform of the rural land system, it is necessary to realize the adaptation and unity of the principle of legal texts and the operational rules.

4.5.8. The Dispute Mediation System Is Not Perfect

The existing dispute resolution mechanism relies too much on the dual path of administrative mediation and judicial litigation and fails to effectively activate the endogenous negotiation and governance resources of rural society. The dual squeeze of the decay of the authority of non-governmental mediation organizations and the high cost of judicial remedies has forced farmers to fall into a passive situation when their rights and interests are damaged. To construct a dispute mediation system with pluralistic co-governance, it is necessary to re-examine the complementary space between formal systems and informal rules and realize the dynamic balance between the rigid authority of the rule of law and the flexible governance of the countryside through the design of procedural cohesion and effectiveness confirmation mechanisms.

5. Policy Recommendations

At present, the transfer of rural land contracting rights in Shandong Province has entered a critical period of deepening reform. With the continuous expansion of the scale of transfer, problems such as institutional obstruction, market mechanism failure,

and social contradictions have become increasingly prominent, restricting the full release of the market-oriented allocation efficiency of land factors [43]. From the rights and interest disputes caused by the non-standardization of contracts to the "non-grain" risks caused by the failure of use supervision; from the Matthew effect, which exacerbates the imbalance of regional development, to the fragility of the social security system for farmers, these deep-seated contradictions need to be systematically solved [44,45]. Based on the empirical analysis conclusions mentioned above, this chapter constructs a multi-level and differentiated policy framework based on the resource endowment and development stage of different regions in Shandong Province, aiming to provide practical solutions for the standardized operation and sustainable development of the rural land transfer market.

5.1. Enhancing Agricultural Modernization Through Targeted Transfer Payments

Basis: The significant positive impact of agricultural modernization on land transfer scale (coefficient 1.265, $p < 0.001$) highlights its role in driving mechanization and large-scale operations, particularly in coastal areas (coefficient 2.903, $p < 0.001$).

To accelerate agricultural modernization, the provincial government should establish a targeted transfer payment system to subsidize the adoption of advanced agricultural technologies, such as precision agriculture, intelligent irrigation systems, and drone-based plant protection. These subsidies should prioritize coastal areas with higher mechanization potential, allocating 60% of the provincial agricultural modernization fund to cities like Qingdao, Yantai, and Weifang to expand smart agriculture pilots and 5G-enabled IoT infrastructure. Inland areas, such as Heze and Linyi, should receive 40% of the funds to focus on high-standard farmland consolidation to mitigate land fragmentation, which restricts mechanization. The transfer payment system should be performance-based, with funds disbursed based on measurable outcomes, such as the increase in mechanized farmland area or the adoption rate of modern equipment (e.g., a target of a 20% annual increase in mechanized farmland in recipient cities).

To ensure efficiency, the provincial government should collaborate with agricultural universities and research institutes to establish technology demonstration zones in each prefecture-level city. These zones would provide farmers with training and access to subsidized equipment, reducing the financial barrier to adopting modern technologies. For instance, a special fund of CNY 500 million annually could be allocated to support 100 demonstration projects province-wide, with priority given to cooperatives and family farms with proven track records in land consolidation.

5.2. Enhancing Rural Land Transfer Efficiency Through Digital Platforms and Flexible Pricing Mechanisms

Basis: Industrial development significantly enhances land transfer (coefficient 0.224, $p < 0.001$), particularly in coastal areas (coefficient 0.419, $p < 0.001$), but information asymmetry and non-standardized pricing hinder market efficiency.

To address market inefficiencies, the provincial government should establish a provincial rural land transfer digital platform integrating data from natural resources, agriculture, and rural affairs departments. This platform, modeled after Qingdao's "land supermarket", should use blockchain technology to ensure transparency in land attributes (e.g., fertility, infrastructure) and transaction records, reducing information asymmetry. The platform should include modules for supply–demand matching, automated value assessment, and risk early warning, targeting a 30% reduction in transaction costs within three years. Coastal cities should pilot cross-regional land transfer auctions to attract industrial and commercial capital, while inland cities should focus on local cooperative-led transfers to build trust.

To address the issue of unreasonable price formation, a flexible pricing mechanism should be introduced, combining a benchmark price with negotiated floating rates. The

provincial agricultural department, in collaboration with academic institutions, should set benchmark prices annually based on land type (e.g., cultivated land, facility agricultural land) and regional economic indicators, such as agricultural product price indices. For example, benchmark prices in coastal areas could range from CNY 1500 to 2000 per mu, while inland areas could range from CNY 800 to 1200 per mu. Operators and farmers should be allowed to negotiate within a ±15% range of the benchmark price, with disputes resolved by a provincial price mediation committee using a "cost compensation + revenue sharing" model. This mechanism balances market-driven pricing with administrative oversight, ensuring fair returns for farmers and incentivizing efficient land use.

5.3. Strengthening Measures to Protect Farmers' Income and Strengthening Farmers' Rights and Interests

Basis: Empirical analysis shows that farmers' income has a negligible effect on land transfer scale (coefficient = −0.452, $p > 0.05$), indicating limited improvement in farmers' well-being. Qualitative findings reveal non-standardized contracts, weak oversight, and inadequate protection of farmer rights, especially for women, the elderly, and migrants. Rural social workers, as community policy intermediaries, can address women's rights, displacement, and resource access issues, enhancing the equity and sustainability of land transfer.

In order to deepen the transfer of rural land contracting rights and protect farmers' rights and interests, it is necessary to build a composite security system of "income growth, risk hedging, and rights recognition" and expand the protection of rights and interests to the dimensions of capacity cultivation, institutional empowerment, and sustainable development [22]. The core measures include cultivating non-agricultural industries with rural characteristics (such as intensive processing of agricultural products, rural tourism, and traditional handicrafts), creating local employment opportunities, activating local economic vitality, and enhancing farmers' employment competitiveness in non-agricultural fields through a gradient vocational training system, ensuring a stable source of income, reducing dependence on land, and promoting the orderly flow of land elements [46].

Rural social workers should promote women's awareness of land contracting and transfer policies through community education and legal consultations, ensuring women's land rights are registered during "rights confirmation". According to the Shandong Women's Federation (2016), 94% of rural villages in Shandong had included women's names on land rights certificates by 2016, surpassing the national average of approximately 80%. It is recommended to establish "Women's Land Rights Support Centers" led by social workers in each county, providing legal aid and advocacy to increase the registration rate to 98% by 2027, aligning with national benchmarks. Social workers should also collaborate with agricultural extension specialists to train female farmers in precision agriculture, enhancing their participation and economic returns.

Land transfer may lead to displacement by revoking farmers' land use rights, particularly during non-agricultural land approvals. Rural social workers and rural development practitioners should conduct community risk assessments to identify vulnerable groups, such as the elderly and low-income farmers. Each township should establish a "Land Transfer Risk Assessment Team" comprising social workers, agricultural experts, and public health professionals to monitor risks and implement interventions. Collaborating with community outreach workers to provide re-employment training and psychological support aims to achieve an 80% re-employment rate for landless farmers by 2027.

In terms of social security and the prevention and control of the risk of returning to poverty, we have improved the linkage mechanism between rural subsistence allowance and medical assistance, and set up a special pension subsidy system for land transfer, so as to eliminate the worries of those who have moved out of the household [47,48].

Optimize the income distribution mechanism and strengthen the rule of law guarantee, let farmers share the operating dividends through shareholding in cooperatives and other forms, and enhance their market dominant position and risk response ability. In addition, we will promote the "enterprise + farmer" order planting model, set up a buffer fund for market price fluctuations, ensure the smooth sale of agricultural products, diversify income sources, enhance farmers' ability to resist market risks, and promote the smooth progress of market-oriented reform of land elements.

5.4. Implementing Differentiated Regional Strategies

Basis: Heterogeneity analysis shows that agricultural modernization and industrial development have a stronger impact in coastal areas than inland areas, reflecting differences in resource endowments and infrastructure.

The provincial government should adopt a differentiated transfer payment system to address regional disparities. Coastal areas should receive 55% of a CNY 2 billion annual agricultural development fund to support industrial integration models, such as vertical integration of vegetable production and processing in Weifang or technology incubators in Qingdao. These funds should target a 15% annual increase in large-scale land transfers (over 50 mu) by 2027. Inland areas should receive 45% of the funds to support a composite trusteeship model, as exemplified by Heze's three-level custody system, which includes village coordination, township supervision, and county-level insurance. This model should aim to consolidate 20% of fragmented farmland in inland cities like Jining and Linyi within five years.

To mitigate the Matthew effect, the provincial government should introduce an inter-regional resource reallocation mechanism. A cross-regional trading platform for cultivated land occupation and compensation indicators, modeled after Weifang–Heze collaborations, should be scaled up to redirect CNY 500 million annually from coastal to inland areas for land consolidation and irrigation upgrades. This mechanism would balance development by ensuring that inland areas receive infrastructure investments proportional to their agricultural output potential (e.g., 30% of provincial irrigation funds to Heze and Liaocheng).

5.5. Strengthening Institutional and Legal Frameworks

Basis: The prevalence of non-standardized contracts and vague definitions of management rights restricts land transfer efficiency, as evidenced by the qualitative findings.

To address institutional gaps, the provincial government should revise local regulations under the Rural Land Contract Law to clarify management rights, including mortgage and shareholding provisions. A provincial management right transaction verification platform should be established, requiring mandatory filing for transfers exceeding 50 mu, with a target of 100% compliance by 2027. This platform should integrate with the digital land transfer platform to ensure real-time tracking of land use, reducing "non-grain" risks.

To enhance dispute resolution, a multi-tiered mediation system should be funded through a CNY 50 million annual transfer payment. This system would include village-level ethical consultation, county-level professional arbitration, and prefecture-level intelligent mediation using AI and blockchain for evidence storage. The system should aim to resolve 85% of disputes at the village or county level, reducing judicial costs for farmers.

These policy recommendations leverage the empirical findings to propose a cohesive strategy that enhances agricultural modernization, optimizes market mechanisms, protects farmers' rights, addresses regional disparities, and strengthens institutional frameworks. By integrating transfer payment systems with digital and legal innovations, Shandong Province can maximize the efficiency of rural land transfer, ensure equitable benefits for farmers, and pave the way for sustainable agricultural modernization.

6. Conclusions

Taking Shandong Province as a case study, this study explores in detail the factors influencing the transfer of rural land contracting rights and analyzes its internal relationship. Through systematic theoretical analysis and empirical testing, this study reveals the core value of rural land transfer mechanisms in promoting the optimization of resource allocation and improving agricultural productivity and identifies the key factors restricting the efficiency of land transfer. This study not only deepens the understanding of land transfer but also provides a solid scientific basis for policy formation. The theory of optimal allocation of resources and economies of scale has laid a solid theoretical foundation for the analysis of the key operation and impact effects of land transfer [48]. Land transfer promotes the transfer of resources from inefficient rural households to efficient business entities and realizes the optimization of resource allocation. Large-scale operation significantly reduces the cost of unit land and enhances the economic benefits of agricultural production and the efficiency of technology application [49]. This finding not only confirms the previous theoretical hypothesis but also strengthens the necessity of promoting agricultural modernization and upgrading the rural industrial structure.

Analysis of panel data for 16 cities in Shandong Province and the relevant policy documents and reports showed that the area under rural land transfer is increasing annually, and agricultural modernization and industrial development have a significant positive impact on rural land transfer. In practice, there are several challenges, including poor contract standardization, insufficient management of land transfer and use, and imperfect protection mechanisms for farmers' rights and interests. This phenomenon shows that to promote rural land transfer, it is particularly important to strengthen institutional construction and policy support.

In order to effectively address the above challenges and promote the healthy development of the land transfer market, this study proposes a series of specific strategies, including promoting the application of modern agricultural science and technology, improving the overall level of agricultural modernization, and broadening the channels for farmers to increase their income. The aim is to enhance the economic strength and income of rural households, which can be achieved by cultivating non-agricultural industries and providing vocational skills training. At the same time, the development of agricultural product processing, leisure agriculture, and rural tourism should be encouraged and supported in order to extend the agricultural industry chain, enhance land value, and promote industrial progress. It focuses on the construction and optimization of irrigation facilities, power supply, and transportation networks, aiming to improve the living environment in rural areas, the quality of public services, and infrastructure construction.

In summary, through the implementation of strategies including improving the degree of agricultural modernization, enhancing farmers' income, promoting industrial development, and improving infrastructure, we can effectively promote the steady development of the rural land transfer market in Shandong Province and accelerate the pace of agricultural modernization. Finally, it will optimize the allocation of land resources, improve agricultural production efficiency, and provide impetus for the sustainable development of rural areas.

Based on current research, this study is constrained by the lack of micro-level data on individual farmers' decision-making processes. Future research could incorporate household survey data or longitudinal interviews to deepen understanding of the behavioral drivers of land transfer. Additionally, expanding the sample scope and data granularity could further elucidate the mechanisms underlying land transfer. Amid the advancing strategies of new urbanization and rural revitalization, reconciling conflicts among stakeholders and ensuring the fairness and transparency of the rural land transfer market remain

critical challenges. This study seeks to offer actionable insights for policymakers to foster substantial progress in Shandong Province and nationwide, advancing agricultural modernization and rural economic prosperity in the new era.

Abbreviations

The following abbreviations are used in this manuscript:

MDPI	Multidisciplinary Digital Publishing Institute
DOAJ	Directory of open access journals
TLA	Three-letter acronym
LD	Linear dichroism
lny_{it}	Total power of agricultural machinery
$Modern_{it}$	Modernization of agriculture
$Controls_{it}$	Control the collection of variables
$Lnincome_{it}$	Farmer's income

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