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# The Impact of Farmland Transfer on Urban–Rural Integration: Causal Inference Based on Double Machine Learning

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**Abstract:** Urban–rural fragmentation represents a significant challenge encountered by nations globally, particularly in both developing and developed contexts, during the modernisation process. This study examines the effects of rural land system reform on facilitating integrated development between urban and rural areas. The analysis of the impact of the 2010 liberalisation of the land transfer policy employs a dual machine learning model, utilising provincial-level data from China spanning 2005 to 2022, to address the limitations of traditional causal inference models while ensuring estimation accuracy. The findings indicate that the reform of the rural land system significantly enhances integrated urban–rural development, particularly in demographic, economic, and ecological dimensions. The mechanisms encompass the facilitation of extensive land and agricultural service operations, the development of new business entities, the migration of rural labour, and the enhancement of agricultural capital. Furthermore, notable disparities exist in the effects of reforms across various regions, particularly concerning urban–rural integration development and land transfer levels. The policy effects of land transfer exhibit a marginally diminishing trend. The influence of land transfer on urban–rural integration varies with economic development levels, demonstrating a nonlinear relationship, with the most pronounced effects observed in regions with moderate economic development. Additionally, the policy effects of land transfer differ based on geographic location. The impact of land transfer policies varies across geographic regions, with the central region exhibiting the most significant effect, followed by the north-eastern region, the western region, and the eastern region, which shows the least effect. This study provides a reference for advancing the reform of the marketisation of land factors, improving the efficiency of land resource allocation, and regionally and in multiple layers advancing the reform of the rural land system.

**Keywords:** reform of the rural land system; large-scale agricultural operations; new types of agricultural business entities; transfer of rural labour force; deepening of agricultural capital; integrated urban–rural development

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## 1. Introduction and Literature Review

### *1.1. Introduction*

Urban–rural ties constitute essential economic and social dynamics, with several countries worldwide examining the framework of these relations during urbanisation, in alignment with their national contexts [1]. The enduring urban–rural dual structure in China has intensified the issue of uneven urban–rural growth, significantly hindering the modernisation of agriculture and rural regions as well as balanced urban–rural progress. Following the 18th National Congress of the Communist Party of China (CPC), China has made substantial strides in addressing the issue of unbalanced urban–rural development and dismantling the urban–rural dual structure by systematically promoting the citizenship of the agricultural transfer population, persistently enhancing the rural land system reform, and comprehensively advancing the equalisation of fundamental public services in urban and rural areas. Nonetheless, China's integrated development of urban and rural areas continues to encounter challenges, including obstacles in augmenting farmers' earnings, inadequate circulation of urban and rural resources, and deficient governance institutions in both urban and rural contexts. For instance, regarding the urban–rural income disparity, a critical measure of the efficacy of integrated urban–rural development, data from the National Bureau of Statistics of China indicate that the ratio of disposable income per capita for urban and rural residents was 2.39 in 2023, reflecting a mere decline of 0.49 since 2012.

The unrestricted movement of urban and rural elements is essential for advancing the integrated development of urban and rural regions. Both Marx and Engels' "urban–rural integration theory" [2], and Lewis's "urban–rural dualism" [3] underscore the symbiotic and integrated link between urban and rural areas, founded on factor interaction. As a spatial carrier of human activities and socio-economic growth, land is an important factor in production. The land system coordinates the possession, dominion, and use of land, which promotes the functioning of land and the development of productive forces. It is an important aspect of the relations of production. Through the two possible factor allocation effects of the "marginal output levelling effect" and the "transaction gain effect", the land transfer policy encourages the multidimensional integration and development of economic production, social life, and the ecological environment between urban and rural areas [4].

Since the establishment of New China in 1949, China has implemented multiple reforms of the rural land system. These reforms have not only liberated and developed rural productive forces but have also contributed positively to maintaining rural stability, enhancing the lives of peasants, and advancing the construction of socialist modernisation. Since the reform and opening up of China, the country has achieved significant progress in reforming and developing the rural land system, which has notably contributed to the advancement of the rural economy [5]. The reform of the rural land system has stimulated agricultural production and empowered farmers to allocate labour resources independently. Consequently, many surplus agricultural labourers have migrated from rural areas to urban centres, facilitating the urban–rural resource reallocation that characterises the "Chinese Miracle" [6]. The transfer of agricultural land serves as a significant policy instrument for addressing the "three rural issues" and has emerged as a crucial governance mechanism for optimising the allocation of rural land resources and improving agricultural production efficiency [7], increasingly serving as a significant method for dismantling the urban–rural divide and fostering integrated urban–rural development.

The marginal rate of return of capital and labour is diminishing as China's economy moves from high-speed growth to high-quality development. The new growth pole of the economy will be the market allocation of land as a factor. Thus, reforming the rural land factor system will inevitably become an important task in the reform of the economic system [8]. In order to support the regeneration of rural areas and the common pros-

perity for all, it is crucial to study how land transfer policies affect integrated urban and rural development.

Contemporary researchers have performed comprehensive investigations into urban–rural issues, establishing a solid theoretical foundation for this piece; yet, research gaps remain. Currently, the majority of research on rural land system reform focuses primarily on the economic growth impacts of land system pilot programs. Most studies on China's rural land system reform and urban–rural integration primarily examine the reform of rural land systems within the framework of urban–rural integration, predominantly focusing on theoretical analysis, with limited empirical investigation. Further investigation is warranted. Secondly, regarding empirical study, urban–rural integration encompasses multidimensional integration. Most current empirical research employs conventional causal identification techniques, such as Difference-in-Differences (DID) and Propensity Score Matching Difference-in-Differences (PSM-DID), to evaluate the outcomes following the development of a multidimensional comprehensive index of urban–rural integration. Nonetheless, these methodologies possess certain constraints regarding their application to the processing of multidimensional data and intricate causal linkages. They encounter the "high-dimensionality trap" and may struggle to discern pure causal effects. The integration of urban and rural development encompasses numerous dimensions, including economic, social, spatial, and ecological factors. Nonetheless, current research is somewhat one-dimensional or insufficiently detailed in its analysis of various dimensions. Furthermore, China is an expansive nation, and there are regional disparities in the implementation of land circulation rules. The current study is deficient in examining regional variability about the "land circulation rate". Consequently, while current studies have demonstrated the significance of land system reform in facilitating urban–rural integration, the fundamental mechanisms and pathways have not been thoroughly and reliably experimentally examined.

In light of this, the following areas of prior study are expanded upon in this paper: This paper delves into the theoretical level of "double-scale" land and service operations, new management main body cultivation, agricultural labour force transfer, agricultural capital deepening, etc., to uncover the inner workings of the "land transfer" policy, which is a symbol of the rural land system reform that impacts urban–rural integration. An integral mechanism of urban–rural integration is exposed by the "land transfer" program, which represents a reform of the rural land system. As a second point, using dual machine learning models to evaluate the "land transfer" policy's impact sidesteps the "curse of dimensionality" and modelling bias inherent in conventional econometric models, bolstering the reliability of the findings. Additionally, this study can enhance the reliability of the study's findings. Last but not least, this paper conducts empirical tests of the influence mechanism and heterogeneity to bolster the theoretical reasoning. This will lay the groundwork for future research that can further reform the rural land system and promote integrated development of rural and urban areas.

### *1.2. Literature Review*

The academic community has produced significant research outcomes regarding land system reform. These studies examine the current state of China's agricultural land system, its correlation with economic performance, and the factors contributing to variations within the system [4]. Additionally, these studies investigate the mechanisms through which land management innovation facilitates the movement of development factors [9], changes in land use, and adjustments in rural structure [10,11]. Empirical analyses are conducted on the policy impacts, spatial heterogeneity, and spill-over effects of land system pilots [12]. Scholars have conducted in-depth analyses of the factors influencing urban–rural

integration and development, including digital finance [13], the digital economy [14], the market economy, government intervention, and social integration-driving mechanisms [15]. They have also proposed targeted improvement strategies.

Nevertheless, the majority of existing research has focused on the impact of land system reform on a specific aspect of urban–rural integration, while fewer have explicitly examined the impact of land system reform on the development of urban–rural integration. P. Serra, A. Vera, A.F. Tulla (2014) [16], and M. Sofer (2013) [17], among others, investigated the correlation between land system reform and the evolution of urban and rural space. Dorosh P, et al. (2010) [18] and Haller, Andreas (2014) [19] investigated the relationship between land system reform and urban and rural economic and social development. Chen K Q, et al. (2020) [11] and Malin Song, et al. (2020) [20] established an analytical framework for the driving mechanism of land use change in coordinated urban–rural development and quantitatively analysed the relationship between land resource utilisation efficiency and coordinated urban–rural development. The coordinated development of urban and rural elements through comprehensive land management was empirically tested by Yuyao Zuo et al. (2023) [21].

Researchers have identified that inadequate circulation of resources between urban and rural areas has led to various issues, including market segmentation and inefficient allocation of factors. The identified issues are fundamental to the imbalance in the economic and social frameworks of urban and rural regions, contributing to the intensification of duality. Land serves as the essential connection between urban and rural development, facilitating the seamless movement of resources between these areas. Reforming the rural land system is a fundamental catalyst for advancing integrated urban–rural development [22]. The transfer of rural land enhances land use efficiency [23], which in turn increases farmers' income [24], reduces the urban–rural income gap [23], promotes the convergence of factor returns, and facilitates the integrated development of urban and rural economies and production. The transfer of rural land has facilitated the development of the rural economy [25], enhancing the equalisation of basic public services and promoting the integrated development of urban and rural social life. The transfer of rural land has significantly enhanced green total factor productivity [26], thereby facilitating the integrated development of urban and rural ecological environments. Promoting the integrated development of urban and rural areas requires the establishment of an effective mechanism for the circulation of urban and rural factors and value enhancement. This involves facilitating a two-way flow and balanced sharing of these factors, ultimately leading to the creation of a comprehensive urban–rural integrated regional system that encompasses various dimensions, including economic, social, demographic, spatial, and ecological aspects [27].

In summary, current research offers valuable insights for this paper. Scholars have extensively discussed the transfer of agricultural land management rights, addressing aspects such as origins, definitions, and future trends. Additionally, they have analysed urban–rural integration and development through various dimensions, including theoretical frameworks, characteristics, construction pathways, impact assessments, and evaluation metrics. Nevertheless, research that integrates the analysis of the specific role mechanism of land management rights transfers in urban–rural integrated development remains limited and consists primarily of preliminary explorations. Current research on the reform of the rural land system aimed at promoting urban–rural integrated development primarily focuses on reducing the income disparity between urban and rural residents and enhancing green total factor productivity. However, urban–rural integrated development encompasses a multidimensional integration across economic, social, cultural, and other domains. There is a notable deficiency in empirical studies examining the comprehensive effects of agricul-

tural land transfer on the multidimensional integration of urban and rural development. Furthermore, the majority of current research remains theoretical, lacking comprehensive analysis regarding the impact of the rural land system reform, specifically China's "land transfer" system, on urban–rural integration at the macro level. There is a notable absence of critical evidence for causal identification.

In addition, in terms of empirical methods, throughout the previous literature, methods such as double difference, synthetic control, and propensity score matching are often applied in the assessment of policy effects. However, there are several drawbacks to the aforementioned approaches when it comes to premise assumptions, sample selection, and data characteristics. Various methods, including the entropy value method, have been employed to assess the level of urban–rural integration. However, when controlling for multiple control variables, the results were not pure, and the researchers fell into the "dimensionality trap" because they relied on traditional measurement tools like DID and PSM-DID [28]. Chernozhukov et al. (2018) suggested a twofold machine learning model that adequately depicts the nonlinear connection between variables [29]; based on the idea of orthogonalisation, the influence of high-dimensional confounding variables on the "quasi-natural experiment" is eliminated from the model, so as to obtain an unbiased estimation of the policy disposition effect under limited samples, and the regularity bias in the machine learning model is solved by the "instrumental variable method". The problem of regularity bias in machine learning models is solved by the "instrumental variables method". Yang et al. (2020), Tao Zhang and Junchao Li (2023), and Jinhe Jiang and Shan Huang (2024) are among the researchers who are now using it in causal inference [30–32].

This research uses this information to build a quasi-natural experiment including the 2010 "land transfer" policy. It then uses the Dual Machine Learning model (DML) to examine the policy's effect and the influence mechanism of land system reform on urban–rural integrated development.

This paper is organised as follows: the Section 2 reviews the policy background, conducts a theoretical analysis, and presents the research hypotheses; the Section 3 details the model setting, variable selection, and data sources for dual machine learning; the Section 4 analyses the empirical results; and the Section 5 concludes with a discussion.

## 2. Theoretical Analysis

### *2.1. Direct Effects of the Reform of the Rural Land System to Promote Integrated Urban–Rural Development*

The logical distribution and efficient allocation of urban and rural resources are essential for attaining integrated urban and rural development, while the transfer of agricultural land can expedite this process [33,34]. On one side, through interaction and integration with urbanisation, farmers will be able to partake in its advantages [35]; conversely, by the logical allocation of urban and rural resource components, the "triple effect" of urban–rural integration concerning planning, infrastructure enhancement, and sustained economic benefit growth will be achieved, so ultimately facilitating urban–rural integration [36,37]. Land transfer positively influences the integration and development of urban and rural communities across various aspects [23,35]. The transfer of agricultural land can significantly enhance land use efficiency [23], thereby increasing the income of agricultural households [17], reducing the wealth disparity between urban and rural regions [23], facilitating the convergence of factor returns, and achieving the integrated development of urban and rural economic production [38]. Secondly, the transfer of agricultural land has significantly advanced the economy of rural areas [5,25], and multidimensional poverty in rural areas has been alleviated [39]; it has resulted in the equalisation of fundamental public services and the cohesive development of social life in both urban and rural re-

gions [40]. Finally, the transfer of agricultural land significantly enhances green total factor productivity [26], facilitating the ambiguity around green development and the cohesive advancement of urban and rural ecosystems.

**Hypothesis 1.** *This study posits the notion that reforming the rural land system can facilitate integrated urban–rural growth.*

### *2.2. Mechanisms via Which Rural Land System Reform Facilitates Integrated Urban–Rural Development*

Firstly, the transfer of agricultural land facilitates the integrated development of urban and rural regions by advancing large-scale agricultural enterprises. Two avenues exist for extensive agricultural enterprises in China: expansion of large-scale activities via the consolidation of agricultural land and services and large-scale activities via the outsourcing of productive services [35,41,42]. The transfer of agricultural land is essential for large-scale land operations, as it optimises land resource allocation by concentrating it among farmers with superior productivity and management skills. This process enhances farmers' involvement in large-scale service operations, thereby fostering the integrated development of urban and rural regions [35,43]. On the one hand, the conveyance of agricultural land facilitates the extensive management of agricultural land [10], achieves the optimal utilisation of resources and economies of scale in extensive land operations [44], includes family farms and other large-scale agricultural land producers, as they will maximise the number of mechanical connections [9], offers multi-link vertically integrated services to adjacent farms to facilitate the incorporation of small farmers into the advancement of modern agriculture [5], and promotes the large-scale operation of agricultural services [23]. On the other hand, with the progression of moderate-scale agricultural operations, the rural economy has evolved from a singular focus on agricultural production to diversification. This moderate-scale approach has aligned agricultural production and rural economic development with modernisation and marketisation, thereby facilitating the profound integration of urban and rural economies [45].

Secondly, the transfer of agricultural land fosters the integrated growth of urban and rural regions by enabling the establishment of new agricultural enterprises [46]. The reform of the rural land system has facilitated the bidirectional movement of land and labour resources in agriculture and rural regions [47,48], addressing the need for extensive, contiguous land for new agricultural enterprises, hence enhancing the scale and intensification of agricultural production [6,48,49]. This reform has facilitated the efficient use of land resources, hence providing substantial assistance for new agricultural business units and promoting competitive agricultural firms. The establishment of new agricultural management entities and the reallocation of agricultural land have effectively enhanced agricultural labour productivity and facilitated the migration of surplus agricultural labour [50,51], contributed to the expansion of agricultural production, and provided labour factor support for integrated urban–rural development.

Thirdly, the conveyance of agricultural land will further advance urban–rural integration by enabling the movement of labour [20]. On the one hand, the conveyance of agricultural land underpins the transition of agricultural labour [43], which facilitates the migration of rural labour, leading to a significant influx of rural workers into other sectors [23], even promoting the upgrading of the form of rural labour transfer through entrepreneurship [52]. Studies indicate that in China, the household contract responsibility system and land transfer policies have promoted the growth of agricultural scale and the urbanisation of the rural labour force [53], and the reform of homesteads has significantly improved the asset mobility of farmers. In Spain, EU agricultural policies have facilitated the modernisation of agriculture, economic diversification, and intensive land use. This

progress has been supported by a developed land transfer market and enhanced off-farm employment opportunities [53]. On the other hand, the integration of the labour market between urban and rural areas is a crucial factor in advancing urban–rural integration and development [15], and labour mobility between urban and rural areas enhances the transfer of information and technology from urban to rural regions. The transfer of agricultural land facilitates labour migration [54]. Additionally, it facilitates the transfer of technology and information via labour market mobility, thereby enhancing the inherent dynamics of urban–rural integration [55,56].

Fourthly, the transfer of agricultural land enhances integrated urban–rural development by facilitating the deepening of agricultural capital [14]. The free flow of agricultural land may have a transaction gain effect, whereby the increased transactionality of agricultural land increases the probability of success for outflowers of agricultural land to find inflowers of agricultural land in times of need, as well as the probability of investment in agricultural land to realise its value, thus increasing the incentives for farmers to make investments in agricultural land [4]. The impact of transaction gains results in the inevitable deepening of agricultural capital through the transfer of agricultural land [38]. Agricultural capital deepening enhances agricultural productivity and industrial competitiveness by integrating advanced technology, equipment, and capital [5]. With the transfer of land, farmers can participate in modern agriculture through capitalisation, which promotes agricultural scale and industrialisation. The enhancement of agricultural capital has elevated the overall rural economy and facilitated the flow and integration of urban and rural resources [34,45], facilitating the reduction of the urban–rural divide and expediting urban–rural integration [57]. Current research indicates that the transfer of agricultural land facilitates the enhancement of agricultural capital [43], which facilitates the integration and development of urban and rural areas. The transfer of agricultural land has resulted in its allocation to agriculturally productive farmers [35], stimulating land consolidation and increased capital investment by farmers [58]. This process is essentially a process of densification of agricultural capital. On the other hand, agricultural capital deepening is a powerful support for urban–rural integrated development, and both rural financial development and agricultural capital inputs have a direct promotion effect and a positive agglomeration effect on urban–rural integrated development [13].

The deepening of rural land system reform has enhanced the connection between urban and rural areas by systematically guiding land factors, facilitating the two-way flow and optimal allocation of essential urban and rural resources, such as land, labour, and capital, and improving the efficiency of resource allocation and factor organisation. This reform significantly impacts the economic activities of primary land users, leading to a comprehensive transformation of employment, industrial, and social structures, as well as spatial layouts and ecological environments. It fosters the emergence of a new urban–rural integration pattern, characterised by mutual promotion between industry and agriculture, complementary development between urban and rural areas, and collective prosperity (the transmission mechanism of land circulation to promote the integrated development of urban and rural areas is shown in Figure 1).

**Hypothesis 2.** *On this basis, this paper proposes the hypothesis that through fostering "double-scale" agricultural operations, developing new subjects in agricultural management, transferring rural labour, and deepening agricultural capital, the reform of the rural land system promotes urban–rural integrated development.*

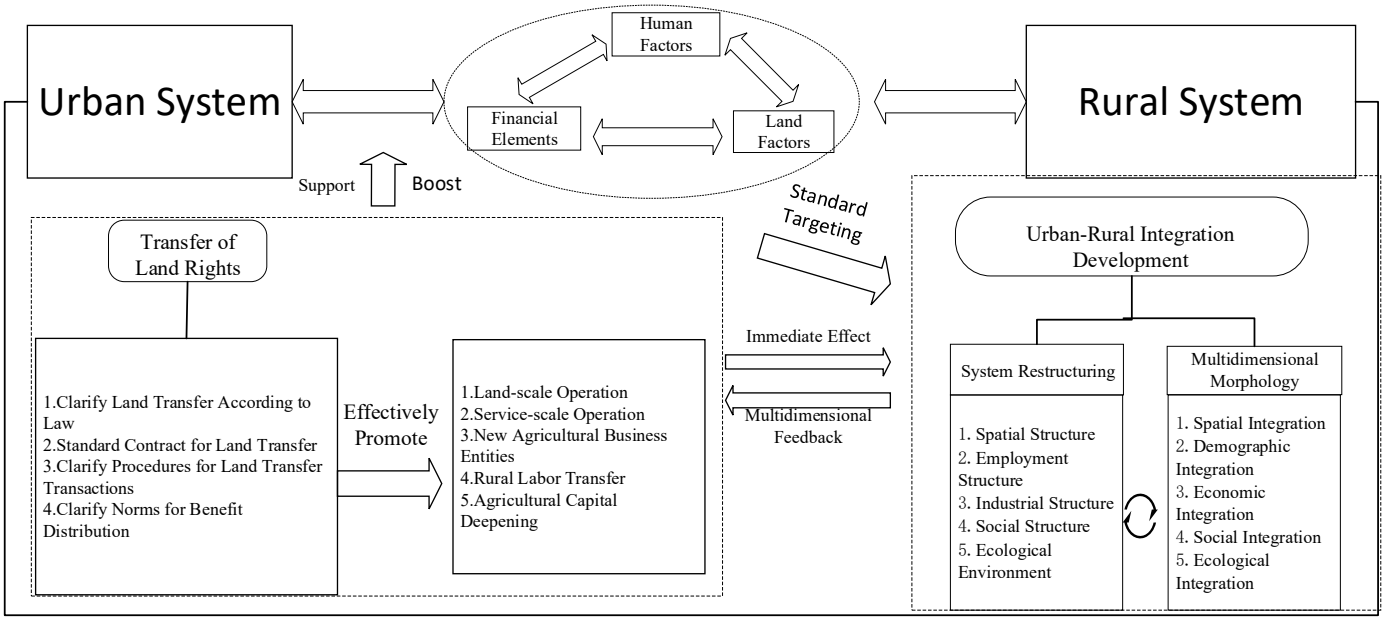



**Figure 1.** Research theoretical framework diagram.

## 3. Methodology and Design

### *3.1. Study Area*

In this work, the focus is on provincial administrative units in China, and the study area is China itself. The urban–rural divide is especially glaring in China, the most populous developing nation in the world. It is both theoretically and practically important to examine how the transfer of agricultural land in China has affected urban–rural integration and growth. China has long pursued a plethora of land system reforms and urban–rural integrated development strategies and pilot projects in an effort to resolve the urban–rural contradiction. The China Rural Management Statistics Annual Report reveals that between 2005 and 2022 there was an increase in the total area of family-contracted arable land transferred in China, from 54,673,800 mu to 57,627,969 mu, and the land transfer rate went from 4.57% to 36.73%, all regarding land transfer laws and practices. With the legal level clarifying the procedural and legal features of land transfer in 2010, the land transfer rate has been steadily increasing, providing abundant data and instances for study. Studying the effects of agricultural land transfer on urban–rural integration and development can provide a more holistic perspective if the focus is on provincial administrative units in China, which vary greatly in terms of economic development, resource endowment, and policy implementation.

### *3.2. Modelling Design*

This article will empirically examine how reforms to the rural land system have affected the growth of urban–rural integration, building on the theoretical analyses that came before it. In the present context of big data research, machine learning offers a distinct advantage in causal inference over ordinary multiple linear regression models, which suffer from two main flaws: estimation bias due to nonlinear relationships between variables and the curse of dimensionality due to an excess of covariates [59]. Referring to Chernozhukov et al. (2018) [29], the following is the construction of a partial linear model for dual machine learning in this paper:

$$URI_{it} = \theta_0 LAND_i * I_t + g(X_{it}) + U_{it} \quad (1)$$

$$E(U_{it}|LAND_i * I_t, X_{it}) = 0 \quad (2)$$

Among them, $URI_{it}$ is the degree of urban–rural integration in province i in year t, $LAND_i * I_t$ is an interaction term between the level of land turnover and the policy time dummy variable, $I_t = 0$ before 2010 and $I_t = 1$ in 2010 and later. $\theta_0$ is the disposal factor and $X_{it}$ is the set of control variables, which may contain obfuscated variables that affect both $URI_{it}$ and $LAND_i * I_t$. The exact form of the function $g(X_{it})$ is unknown. In this paper, a machine learning algorithm is used to obtain its estimation $\hat{g}(X_{it})$. $U_{it}$ is the error term with a conditional mean of zero.

If the machine learning algorithm is used to solve $g(X_{it})$ in the above model directly, the estimated coefficient $\hat{\theta}_0$ obtained at this point is a regularised estimator, which is biased under finite samples, and, therefore, further auxiliary regressions are constructed.

$$LAND_i * I_t = m(X_{it}) + V_{it} \tag{3}$$

$$E(V_{it}|X_{it}) = 0 \tag{4}$$

where the error term is $V_{it}$, the functional form is unknown, and the conditional mean is 0. Therefore, in this paper, we use the machine learning algorithm to estimate $\hat{m}(X_{it})$ and use it to construct the residual estimation $\hat{V}_{it} = \hat{V}_{it}LAND_i * I_t - \hat{m}(X_{it})$, and then we use the same algorithm to estimate $\hat{g}(X_{it})$ in the main regression to obtain $Y_{it} - \hat{g}(X_{it}) = \theta_0 D_{it} + U_{it}$ and regress $\hat{V}_{it}$ as an "instrumental variable" for $\hat{V}_{it}LAND_i * I_t$. The coefficient estimates are obtained as follows:

$$\hat{\theta}_0 = \left(\frac{1}{n}\Sigma_{i\in I,t\in T}\hat{V}_{it}LAND_i * I_t\right)^{-1}\frac{1}{n}\Sigma_{i\in I,t\in T}\hat{V}_{it}(Y_{it} - \hat{g}(X_{it})) \tag{5}$$

At this point, the convergence speed of $\hat{\theta}_0$ will depend on the convergence speed of $\hat{g}(X_{it})$, $\hat{m}(X_{it})$ to $g(X_{it})$, and $m(X_{it})$; for two-machine learning estimation on the one hand, it is conducive to exclude the disposal variable $LAND_i * I_t$ in the influence caused by the confusing set of variables $X_{it}$; on the other hand, it is able to accelerate the speed of convergence of $\hat{\theta}_0$ and thus obtain an accurate estimation under the limited samples.

In addition, this paper employs the 5-fold split fitting method in the regression to address the regression samples, thereby enhancing the stability and reliability of the model estimation. The final estimation result is the median-adjusted result, which is obtained by repeating the sampling 101 times [29].

### *3.3. Variable Selection and Data Processing*

#### 3.3.1. Data Sources

This study utilises panel data from 30 Chinese provinces, including autonomous regions and municipalities directly under the central government, excluding Hong Kong, Macao, Taiwan, and Tibet, covering the period from 2005 to 2022 due to data availability constraints. Missing data in this paper are addressed through linear interpolation, while certain data are transformed using logarithmic functions. The urban–rural integration indicator system utilises original data from control variables, land scale operation, service scale operation, rural labour force transfer, and agricultural capital, sourced from authoritative statistical yearbooks, including the China Statistical Yearbook and the China Rural Statistical Yearbook, along with provincial statistical yearbooks. Additionally, data on land transfer and the cultivation level of new agricultural business entities are obtained from the China Rural Business Management Statistical Yearbook. Finally, balanced panel data spanning 18 years from 2005 to 2022 and covering 30 provinces were obtained.

3.3.2. Explained Variable: Level of Urban–Rural Integration

Urban–rural integration represents a multifaceted system characterised by various dimensions and dynamics. The process is evident in the diminishing disparity between urban and rural areas, as well as in the deeper synergy and collaborative development trends emerging between them. This study constructs a comprehensive index of urban–rural integration development, building on existing research results [4,6–8,22,27,36,60–62]. The index encompasses essential indicators that assess urban–rural disparities and includes significant parameters that represent the overall development and progress in both urban and rural regions. The evaluation index system comprises five dimensions: spatial integration (spaint), population integration (popint), economic integration (econint), social integration (socinte), and ecological integration (ecolint). Twenty specific indicators were selected, as detailed in the index system presented in Table 1. These comprise comparative indicators that elucidate the causes of urban–rural integration, driving indicators that illustrate the forces propelling the process of urban–rural integration, and state indicators that represent the stage and condition of urban–rural integration. The assessment of urban–rural integration development was conducted using the scientific method of entropy, which ensured objectivity, comprehensiveness, and scientific rigor in the results. Simultaneously, to emphasise the variations in urban–rural integration development, the assessed index was scaled to a range of 0–100.

3.3.3. Explanatory Variables: Land Transfer Policy Dummy

China's No. 1 central document for 2010 implemented significant modifications to the land transfer policy, emphasising the necessity to enhance support for land transfer and to actively advance the marketisation of land transfer [35]. Simultaneously, it underscores the need of defining the scope of land transfer and acknowledges that the extent of land transfer can more comprehensively reflect the subsequent dynamics of land transfer policy implementation. Consequently, this paper calculates the level of agricultural land transfer as the ratio of family-contracted arable land to family-operated arable land. It uses China's No. 1 central document for 2010 "Several Opinions on Increasing the Efforts to Integrate Rural and Urban Development and Further Strengthening the Basis of Agricultural and Rural Development" as its policy time node, and builds its core explanatory variables using the policy dummy variable and the interaction term of the level of agricultural land transfer ($LAND_i * I_t$) variables. This study uses the core explanatory variables as proxies, and the data are obtained from the China Rural Business Management Statistical Annual Report. To further verify the robustness of the empirical results, it also uses the interaction terms $LANDT_i * I_t$ for the land transfer scale and $LANDC_i * I_t$ for the area of arable land under family contract.

**Table 1.** Index system for urban–rural integration calculation.

| First Class Index | Second Class Index | Weights | Tertiary Class Index | Weights | Definition | Indicator Properties |
|---|---|---|---|---|---|---|
| URI | spaint | 0.2195 | Urban population density | 0.0656 | Urban population/urban area | + |
| | | | Urban road area ratio | 0.0403 | Urban road area/urban area | + |
| | | | Per capita ratio of private cars in urban and rural areas | 0.0068 | Private cars per capita in urban areas/private cars per capita in rural areas | – |
| | | | Urban–rural spatial expansion | 0.1068 | Crop sown area/built-up area | + |
| | popint | 0.1968 | Urbanisation rate | 0.0555 | Urban resident population/total population | + |
| | | | Urban–rural employment coefficient of inversion | 0.0698 | Share of urban residents in employment/share of rural residents in employment | – |
| | | | Urban–rural education coefficient of inversion | 0.0317 | Average years of schooling of urban residents/average years of schooling of rural residents | – |
| | | | Share of non-agricultural employed persons | 0.0397 | Nonfarm payrolls/total employment | + |
| | econint | 0.1018 | Comparison between urban and rural regions' per capita disposable income | 0.0325 | Urban disposable income per capita/rural disposable income per capita | – |
| | | | Comparing urban and rural consumption per capita | 0.0310 | Per capita consumption of urban households/per capita consumption of rural households | – |
| | | | Dual Structure Comparison Coefficient | 0.0158 | (Share of GDP in secondary and tertiary industries/Share of employment in secondary and tertiary industries)/(Share of GDP of primary industry/Share of employment in primary industry) | – |
| | | | Urban–rural Engel's coefficient ratio | 0.0225 | Urban Engel's coefficient/Rural Engel's coefficient | + |

**Table 1.** *Cont.*

| First Class Index | Second Class Index | Weights | Tertiary Class Index | Weights | Definition | Indicator Properties |
|---|---|---|---|---|---|---|
| URI | socinte | 0.1431 | Coefficient of comparison of medical conditions between urban and rural areas | 0.0196 | Number of beds per 10,000 population in urban health-care institutions/Number of beds in rural health-care institutions per 10,000 population | − |
| | | | Comparison of the expenditure on education and recreation between urban and rural areas | 0.0180 | Urban per capita expenditure on education and recreation/rural per capita expenditure on education and recreation | − |
| | | | Social security expenditure comparison coefficient | 0.0839 | Local finance expenditure on social security and employment/local finance general budget expenditure | + |
| | | | The coefficient of comparison for transportation and communication costs in urban and rural locations | 0.0216 | Urban per capita expenditure on transportation and communication/rural per capita expenditure on transportation and communication | − |
| | ecolint | 0.3388 | Ecological greening in urban and rural areas | 0.0995 | Percentage of forest cover | + |
| | | | Air pollution in cities and rural areas | 0.0113 | Regional $SO_2$ emissions/GDP | − |
| | | | Energy conservation and emission reduction in urban and rural areas | 0.0221 | Energy consumption per unit of industrial added value (above-scale equivalent value) | − |
| | | | Management of pollution in urban and rural areas | 0.2059 | Investment in environmental pollution control/GDP | + |

#### 3.3.4. Mechanism Variables

Through the theoretical analysis presented earlier, it can be concluded that land transfer promotes urban–rural integration development through four pathways: advancing the "dual-scale" agricultural operation, fostering new agricultural business entities, facilitating the transfer of rural labour, and deepening agricultural capital. Based on this, the mechanism variables selected in this paper are as follows: Among these, land_scale is determined by the ratio of sown area to the number of agricultural employees, or per capita sown area. Similarly, service_scale is expressed as the ratio of agricultural service output to the number of agricultural employees, or per capita agricultural service output. Similarly, agri_entity measures the cultivation of new agricultural management subjects by looking at the number of agricultural professional cooperatives to the number of people working in agriculture, or the number of cooperatives per 10,000 people. Similarly agri_lab measures the transfer of agricultural labour by comparing the number of people employed in secondary and tertiary industries to the number of people employed in the primary industry. Lastly, the deepening of agriculture is measured by the number of cooperatives per 10,000 people. The China Statistical Yearbook and the China Rural Statistical Yearbook are secondary sources for data pertaining to mechanism variables.

#### 3.3.5. Control Variable

This paper includes controls for other factors that may impact the level of urban–rural integration and development, as well it uses dual machine learning and its regularisation algorithm to handle high-dimensional control variables effectively. This ensures that the policy effect assessment is based on available data and accurate. Here are the exact parameters for setting the control variables for the category of regional development level and the category of agricultural development level:

The following four indicators are set for the level of regional development: level of industrialisation (IDL), measured as the share of GDP attributable to industrial added value; level of informatisation (ILS), measured as the share of GDP attributable to total postal and telecommunications business; level of human capital (HCL), measured as the share of the population attributable to regular college and university enrolment; and level of transport infrastructure (TIS), measured as road mileage.

There are four indicators that are used to measure the level of agricultural development: the level of agricultural mechanisation (AMS), which is the percentage of crop mechanised area relative to the total area of cultivated land; the quality of farmland soil (SFQ), which is the area of soil erosion control; the agricultural water conservation facilities (IWFs), which is the percentage of actual irrigated cultivated land relative to the total area of cultivated land; and the degree of agricultural disaster (ADA), which is the area of farmland affected by disaster.

Furthermore, to enhance the fitted model's accuracy, this paper incorporates quadratic terms for each province variable in the regression analysis. To prevent missing data on the time and province dimensions, individual and year dummy variables are used to introduce fixed effects. The China Statistical Yearbook and China Rural Statistical Yearbook provide the statistics pertaining to the control variables.

Descriptive statistics for the main variables in this paper are shown in Table 2.

**Table 2.** Descriptive statistics for key variables.

| Variable | Mean | SD | Min | Max |
|---|---|---|---|---|
| uri | 64.320 | 5.426 | 42.254 | 75.441 |
| $LAND_i * I_t$ | 0.227 | 0.203 | 0.000 | 0.911 |
| agri_lab | 4.127 | 7.199 | 0.299 | 63.143 |
| land_scale | 7.033 | 4.120 | 0.127 | 29.362 |
| ser_scale | 0.210 | 0.141 | 0.027 | 0.955 |
| agri_capdeep | 5.964 | 13.570 | 0.066 | 141.567 |
| agri_entity | 47.537 | 43.172 | 0.183 | 176.344 |
| IDL | 0.353 | 0.086 | 0.100 | 0.574 |
| ILS | 0.065 | 0.046 | 0.009 | 0.290 |
| HCL | 0.019 | 0.007 | 0.006 | 0.043 |
| TIS | 2.380 | 0.872 | −0.211 | 3.715 |
| AMS | 91.411 | 39.118 | 4.993 | 224.997 |
| SFQ | 4057.134 | 3083.055 | 28.360 | 16,678.700 |
| IWF | 47.144 | 23.337 | 12.467 | 107.919 |
| ADA | 957.933 | 940.156 | 2.000 | 7394.000 |

## 4. Results and Analysis

### *4.1. Policy Review of China's Rural Land System Reform*

In 1978, China implemented the Household Contract Responsibility System, separating land ownership from contractual management rights, laying the foundation for rural land management reform and initiating a new chapter in land transfers [5,10]. In 1988, the revised Land Administration Law strengthened land use control and relaxed restrictions on transfers, promoting legalization [47,63]. In 2010, China's No. 1 central document promoted standardised land transfer contracts and enhanced management to consolidate the basic rural management system and improve the regulation of the transfer market. This policy served as a critical milestone in providing operational guidance for rural land transfers [5,10,64,65]. By 2014, policies emphasised developing appropriately scaled operations and regulating transfers [5,66]. In 2016, the "separation of three rights" (ownership, contract, and management rights) granted land transfers legal status [10]. In 2019, the revised Rural Land Contract Law focused on management and reform, ensuring contract confirmation, registration, and certification, enhancing transfer management and optimising resource allocation [35,45,47,67]. In 2021, the Measures for the Administration of Circulation of Rural Land Contracted Management Right protected collective ownership and farmers' contractual rights while refining operational rights to activate efficient land resource allocation. In 2024, China's No. 1 central document launched the second-round pilot for land contract extensions, improving the price formation mechanism for transfers and preventing unreasonable cost increases, contributing to comprehensive rural revitalization [68].

By combing through the policy evolution, this paper finds that since 2010, when China's No. 1 central document for 2010 explicitly proposed that rural land could be transferred in accordance with the law, land transfer has gradually shifted from a spontaneous behaviour relying on an acquaintance society, to a large-scale and standardised mode of operation. Previously, land transfer was predominantly limited to the conventional network of smallholder farmers, hindering the achievement of vast contiguous operations. The policy directives and institutional standards at the national level have established a robust framework and assurance for the extensive implementation of land transfer [9]. The implementation of this strategy has markedly enhanced the integration and optimisation of land resources [12], while also establishing a temporal framework for examining the effects of land transfer on urban–rural integrated development. This article utilises the policy

variable of "land transfer" to assess the reform of the rural land system and examines the impact of land policy reform on the degree of urban–rural integration and development, supported by robust practical and theoretical foundations.

### *4.2. Policy Effects of Rural Land System Reform on Urban–Rural Integrated Development*

Using a 1:5 sample split and the Random Forest algorithm for both main and auxiliary regressions, this paper estimates the policy effect of "land transfer" on urban–rural integrated development. Table 3 displays the regression results. Based on the results of model (1), which accounts for province fixed effects, year fixed effects, and the main terms of other provincial variables in the full sample interval, it can be concluded that the reform of the rural land system has the potential to enhance the level of urban–rural integration development. The regression coefficient of "land transfer" on this outcome is positive and significant at the 1% level. Model (2) builds on model (1) by further controlling the quadratic term of the provincial variables; on this basis, the value remains relatively unchanged, and the regression coefficient remains consistently positive.

**Table 3.** Benchmark regression results.

| Variables | (1) uri | (2) uri | (3) spuri | (4) pouri | (5) ecuri | (6) souri | (7) eclri |
|---|---|---|---|---|---|---|---|
| $LAND_i * I_t$ | 4.059 *** | 4.044 *** | −0.127 | 0.598 ** | 1.914 *** | −0.146 | 1.203 *** |
| | (0.939) | (0.932) | (0.332) | (0.256) | (0.410) | (0.576) | (0.234) |
| Provincial fixed effects | YES | YES | YES | YES | YES | YES | YES |
| Year fixed effects | YES | YES | YES | YES | YES | YES | YES |
| Control variables (linear terms) | YES | YES | YES | YES | YES | YES | YES |
| Control variables (quadratic terms | NO | YES | YES | YES | YES | YES | YES |
| Constant | −0.000 | 0.005 | 0.023 | −0.019 | 0.032 | 0.008 | −0.010 |
| | (0.082) | (0.082) | (0.019) | (0.024) | (0.036) | (0.057) | (0.029) |
| Observations | 540 | 540 | 540 | 540 | 540 | 540 | 540 |

Robust standard errors in parentheses, *** $p < 0.01$, ** $p < 0.05$.

With the regression coefficients of the "land transfer" policy on spatial integration, demographic integration, economic integration, social integration, and ecological integration presented in models (3)–(7), we can delve further into the ways in which rural land system reform affected the various aspects of urban–rural integration. As far as the policy effect is concerned, the impact of the "land transfer" policy on urban–rural economic and ecological integration is significantly positive at the 1 per cent level, and on urban–rural demographic integration at the 5 per cent level, and the regression coefficients of economic integration are larger than those of ecological integration and population integration. This reflects the directness and priority of economic integration, and the land transfer policy directly changes the allocation efficiency and use of land resources, improves the utilisation of rural production factors, and promotes agricultural modernisation and industrialisation. These changes tend to boost economic growth quickly and enhance economic linkages between urban and rural areas, so the impact of the policy on economic integration is significant and strong. Long-term and indirect ecological integration: land transfer policies may indirectly promote rural–urban ecological integration by optimising land use structures, promoting ecological agriculture and protecting the environment [26]. However, the restoration and improvement of ecosystems usually takes a long time, and the short-term effects of policies may be relatively weaker than those at the economic level, but in the long term, their impacts will gradually become apparent. Complexity and delayed nature of

population integration involves complex factors such as population mobility, migration, cultural identity and social adaptation. It will take more time and additional policy backing, like equalising public services like healthcare, education, and social security, to accomplish deeper integration of the urban and rural populations, even though land transfer policies can indirectly encourage the flow of rural labour to cities [21,69]. Therefore, compared with economic and ecological integration, the effect of policies on population integration may be weaker.

In addition, the "land transfer" policy's negative regression coefficients on urban–rural spatial and social integration fail to pass the significance test, probably because the land transfer policy usually focuses on the productive use of land resources but may not be accompanied by the simultaneous planning of urban–rural spatial infrastructures, such as transport and logistics, which results in the urban–rural spatial and social integration of urban and rural areas. The policy's short-term implementation may not have been enough to eliminate social and cultural disparities between rural and urban residents, such as inequalities in the social security system and the household registration system, which continue to limit the process of social integration, and there has been no significant improvement in spatial segregation.

### *4.3. Ssensitivity Analysis*

The first step is to modify the study population. This article checks the robustness of the empirical conclusions by excluding variables from Beijing, Tianjin, Shanghai, and Chongqing, four Chinese municipalities that are far ahead of other provincial administrative units in terms of policy environment and economic growth. Table 4 (1) displays the regression findings, which demonstrate that the "land transfer" policy's effect on urban–rural integration is statistically significant at the 1% level, proving that the paper's benchmark regression results are solid.

Secondly, we swap out the explanatory variables. Table 4 shows the regression results, and to make sure the empirical results are solid, the study uses two terms that interact with each other, one for the land transfer scale and policy variables ($LANDT_i * I_t$) and another for the family-contracted cropland area and policy variables ($LANDC_i * I_t$). The results from the benchmark regression in this study are robust because, even after removing the principal explanatory variables, the regression coefficients are still significant at the 1% level, suggesting that the findings are well-grounded.

Thirdly, we eliminate the impact of extreme cases. This paper uses a quartile-based method to reduce the number of variables in the baseline regression, with the exception of the disposal variable. At the 1% and 99% quartiles, as well as the 5% and 95% quartiles, the variables are replaced with values that are lower or higher than the corresponding outliers. This is done to prevent biased estimation results, particularly for the urban–rural integration development index synthesised using the entropy weight method. Sections (4) and (5) of Table 4 provide the detailed findings of the regression analysis. Even after excluding extreme cases, the results of this article remained mostly unchanged.

Fourth, think about endogeneity. This research relies on Groves et al. to examine the potential endogenous variable of agricultural land transfer and the potential reciprocal causation between this variable and urban–rural integration and development [61]; an instrumental variable is used to alleviate the endogeneity issue, which is the first-order lagged term of the key explanatory variable agricultural land transfer. The introduction of instrumental factors did not materially alter the results of this work, as shown in Model (6) in Table 4.

**Table 4.** Robustness test regression results.

| | (1) | (2) | (3) | (4) | (5) | (6) | (7) | (8) | (9) | (10) | (11) | (12) | (13) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | **Exclude Municipalities** | **Substitute the Explanatory Variable** | | **Winsorized Treatment** | | **Apply Instrumental Variables** | **Exclude Other Policies** | | | **Change the Splitting Ratio** | | **Change the Machine Learning Model** | |
| **Variables** | | | | **5%** | **1%** | | **Three Rights Separation** | **Three Land Reforms** | **Simultaneous Control** | **Kfold = 3** | **Kfold = 5** | **Gradboost** | **SVM** |
| $LAND_i*I_t$ | 5.034 *** | | | 4.124 *** | 4.198 *** | 7.935 *** | 2.948 ** | 1.965 ** | 3.031 ** | 4.017 *** | 4.145 *** | 3.313 *** | 14.740 *** |
| | (1.306) | | | (0.871) | (0.932) | (1.865) | (1.234) | (0.915) | (1.211) | (1.096) | (1.149) | (1.030) | (1.193) |
| $LANDT_i*I_t$ | | 1.272 *** | | | | | | | | | | | |
| | | (0.196) | | | | | | | | | | | |
| $LANDC_i*I_t$ | | | 1.714 *** | | | | | | | | | | |
| | | | (0.202) | | | | | | | | | | |
| Three Rights Separation | | | | | | | YES | | YES | | | | |
| | | | | | | | | YES | YES | | | | |
| Provincial fixed effects | YES | YES | YES | YES | YES | YES | YES | YES | YES | YES | YES | YES | YES |
| Year fixed effects | YES | YES | YES | YES | YES | YES | YES | YES | YES | YES | YES | YES | YES |
| Control variables (linear terms) | YES | YES | YES | YES | YES | YES | YES | YES | YES | YES | YES | YES | YES |
| Control variables (quadratic terms | YES | YES | YES | YES | YES | YES | YES | YES | YES | YES | YES | YES | YES |
| Constant | 0.053 | 0.312 ** | 0.261 * | 0.029 | 0.023 | 0.038 | 0.009 | 0.032 | 0.039 | −0.044 | 0.045 | −0.039 | −0.732 *** |
| | (0.088) | (0.149) | (0.144) | (0.075) | (0.079) | (0.081) | (0.081) | (0.086) | (0.082) | (0.087) | (0.082) | (0.083) | (0.203) |
| Observations | 468 | 540 | 540 | 540 | 540 | 493 | 540 | 540 | 540 | 540 | 540 | 540 | 540 |

Robust standard errors in parentheses, *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

Fifth, exclude parallel policy effects. In order to ensure the accuracy of the policy effect estimation, this paper controls for other similar policies in the same period. However, there is a potential challenge to the conclusions of this paper's benchmark regression study due to the fact that other policies in the same period will inevitably interfere with the verification of the policy effect of "land transfer" on urban–rural integration and development. "Stabilise the contractual rights of farmers, activate the land management rights, and allow the management rights of contracted land to be mortgaged and financed to financial institutions" was highlighted in the China's No. 1 central document for 2014. The same year, a series of institutional documents formally initiated the reform of the "three rights" of the rural land system. The policy time node in this study is 2014, and the number of land contracting right certificates issued is an interaction term with the policy time node. Reforms to the residential base system in rural regions, the "three land" reform, the reform of rural land expropriation, and the market entrance of jointly operated construction land were all launched by the CPC Central Committee in 2015; this paper takes 2015 as the policy time node, constructs the interaction term land_transi$*I_t$ between rural land transfer revenue and the policy time node, and adds the above variables into the regression analysis. Specific regression results are shown in Table 4 (7)–(9), in the exclusion of the impact of the two parallel policies during the same period, "land transfer" policy effect significance remains unchanged, enough to prove the robustness of the conclusions of this paper.

Finally, step six is to reset the dual machine learning model. First, the paper changed the sample partition ratio of the dual machine learning model from 1:5 to 1:3 and 1:8 to see how it could affect the results. Second, it switched out the machine learning algorithms, using Gradient Boosting and Support Vector Machines instead of the Random Forest algorithm for predictions. This was done to see how it would affect the results. Third, it changed the sample partition ratio back to 1:5 to see how it could affect the results. In Table 4, models (10)–(13) describe the regression results obtained after the dual machine learning models were reset as mentioned above. It is clear that the original conclusion remains robust regardless of the sample partition ratio or prediction algorithm used by the dual machine learning model. Land transfer is found to promote urban–rural integrated development, and the only change is in the size of the policy effect.

### *4.4. Conduction Mechanism Test*

This research uses a dual machine learning framework to investigate how rural land system reform influences the amount of urban–rural integrated development. It then uses Jiang Boat's (2022) approach to confirm the causal mediation impact [4]. The results of the mechanism test are shown in Table 5, and Hypothesis 2 was tested.

**Table 5.** Mechanism test results.

| | (1) | (2) | (3) | (4) | (5) |
|---|---|---|---|---|---|
| **Variables** | **land_scale** | **ser_scale** | **agri_entity** | **agri_lab** | **agri_capdeep** |
| $LAND_i*I_t$ | 3.733 *** | 0.072 *** | 110.469 *** | 9.576 *** | 19.252 *** |
| | (0.626) | (0.026) | (11.320) | (2.521) | (4.184) |
| Provincial fixed effects | YES | YES | YES | YES | YES |
| Year fixed effects | YES | YES | YES | YES | YES |
| Control variables (linear terms) | YES | YES | YES | YES | YES |
| Control variables (quadratic terms | YES | YES | YES | YES | YES |
| Constant | 0.088 * | −0.001 | 0.288 | −0.004 | 0.412 |
| | (0.048) | (0.002) | (0.681) | (0.116) | (0.300) |
| N | 540 | 540 | 540 | 540 | 540 |

Standard errors in parentheses, * $p < 0.05$, *** $p < 0.001$.

Based on the data presented in Table 5, it can be concluded that the land transfer policy has a positive and statistically significant impact on promoting "dual-scale" operation of land and services. This means that the policy can help rural areas modernise their economies, operate services on a large scale, and incorporate urban and rural areas more seamlessly. Suitable circumstances for the merger of urban and rural areas: Scale operation has several positive effects on agriculture, including increased production capacity and efficiency, higher farmer incomes, better rural infrastructure, and a more equitable distribution of resources and better connectivity between rural and urban regions.

As can be seen in column (3) of Table 5, the land transfer policy has positive and statistically significant regression coefficients. This means that the reform of the land system allows the new management subjects to expand into the upstream and downstream industrial chains of agriculture, including processing agricultural products, logistics and distribution, and branding. This, in turn, promotes the optimisation and upgrading of the agricultural industry chain, aligns the structure of the rural economy with market demand, and helps integrate urban and rural areas. As a result, rural economic structures will be better able to meet consumer demand, and the groundwork will be laid for the integration of rural and urban growth.

According to column (4) of Table 5, the land transfer policy has positive and statistically significant regression coefficients, suggesting that it can facilitate the movement of resources from rural to urban areas and the transfer of labour from one region to another. There is more economic, cultural, and social integration between rural and urban regions as a result of farmers migrating to cities, which transfers resources like labour, technology, and money from the countryside to cities.

Column (5) of Table 5 shows that the land transfer policy's regression coefficients are all positive and significant, which means that the policy promotes the agglomeration of agricultural capital—including the convergence of financial, technological, and managerial resources—through the concentration and large-scale operation of land. Additionally, the policy promotes the modernisation of agricultural production and the availability of agricultural financial services. Furthermore, by advocating for land transfer, we can boost agricultural production efficiency and output value while simultaneously transforming the rural economy. This, in turn, makes it easier for resources to flow and integrate between urban and rural regions.

### *4.5. Heterogeneity Analysis*

This paper examines the "land transfer" policy from four angles: economic development, geographic location, degree of urban–rural integration, and the amount of land transferred. Its goal is to shed light on whether or not this policy's impact on urban–rural integration is heterogeneous.

The level of urban–rural integration has heterogeneity. The policy impacts of land transfer vary significantly among areas with varying degrees of urban–rural integration and development, as shown by the regression findings of model (1) in Table 6. Additionally, the rule of marginal decrease of policy effects is applicable in these locations. Land transfer policies have a larger promotion impact in areas with low degrees of urban–rural integration and a smaller policy effect as the amount of urban–rural integration grows, according to the magnitude of the coefficients. Land transfer has a statistically significant impact on policy at the 10%level in the highly integrated group. This indicates that the land transfer strategy may not have as much of a role in encouraging urban–rural integration in places where it already exists. Possible explanations include a lack of need for further integration of facilities and resources in highly integrated regions and a less marginal impact of land transfer. Land transfer policy regression results fail to meet significance criteria in

the medium integration group. This indicates that land transfer's impact in places with medium integration may be less steady, or that other reasons limit the policy's impact in these areas. Land transfer policy seems to have the greatest impact on fostering integration in regions with little urban–rural integration since its coefficient in the low integration group passes the significance test at the 1% level. This could be because land transfer policies encourage more urban–rural integration in areas with more room for policymaking and a better chance of improving the efficiency of resource allocation.

Diversity in land transfer levels: Results from model (2)'s regression analysis in Table 6 demonstrate that the policy impacts of land transfer vary significantly among areas with varying degrees of land transfer. The high-transfer group shows a statistically significant relationship between land transfer and urban–rural integration at the 1% level of significance. This indicates that regions with higher rates of land transfer are better able to promote urban–rural integration through land transfer. This is likely due to the following factors: land transfer has reached a high scale effect, the market mechanism is relatively perfect, and the land resources have been allocated efficiently. Additionally, the benefits and cascading effects of land transfer can significantly promote urban–rural integration. In the group of areas with medium land transfer rates, the regression coefficient of land transfer does not pass the significance test. This suggests that land transfer does not play a significant role in these areas, likely due to factors such as insufficient market support, imperfect institutional support, or inadequate supporting measures. As a result, land transfer may not be able to clearly promote urban–rural integration. The regression coefficient of land transfer is significant at the 1% level in the low-transfer group, suggesting that land transfer policies can still promote urban–rural integration even in areas with low land transfer rates. This could be because land transfer in these areas gives policymakers more room to manoeuvre when it comes to improving the efficiency of resource allocation. Land transfers on a smaller scale may nonetheless have a big impact on integration because of the large marginal effect.

Varying degrees of economic growth: Land transfer policy impacts vary among areas with varying degrees of economic growth, as seen by the regression findings of model (3) in Table 6. Depending on the level of economic development, the impact of land transfer on urban–rural integration varies. In areas with low economic development, land transfer has a significant effect on resource integration and upgrading, but the policy effect is limited by infrastructure and market conditions. This trend is evident in the fact that the high economic development group fails the significance test, the medium economic development group is significant at the 1% level, and the low economic development group is significant at the 10% level. In areas with a medium degree of economic growth, the policy impact of land transfer is largest. This suggests that these regions are now experiencing a golden time of resource integration and integrated development. Policy has less of an impact on more developed regions. This is likely due to the fact that these areas are already well integrated between the city and the countryside, and the marginal gains from transferring land have already been substantial.

**Table 6.** Heterogeneity regression results.

| | (1) | | | (2) | | | (3) | | | (4) | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Variables** | **High-Integration Group** | **Medium-Integration Group** | **Low-Integration Group** | **High-Transfer Group** | **Medium-Transfer Group** | **Low-Transfer Group** | **High-Level Group** | **Medium-Level Group** | **Low-Level Group** | **Eastern Region** | **Central Region** | **Western Region** | **North-Eastern Region** |
| $LAND_i * I_t$ | 2.628 * | 3.131 | 5.434 *** | 12.53 *** | 2.027 | 2.994 *** | 1.314 | 6.180 *** | 6.391 * | 5.210 ** | 11.22 *** | 7.329 * | 7.454 *** |
| | (1.258) | (2.729) | (1.388) | (3.755) | (1.800) | (0.811) | (1.015) | (1.286) | (2.994) | (1.730) | (1.730) | (3.364) | (2.263) |
| Provincial fixed effects | YES | YES | YES | YES | YES | YES | YES | YES | YES | YES | YES | YES | YES |
| Year fixed effects | YES | YES | YES | YES | YES | YES | YES | YES | YES | YES | YES | YES | YES |
| Control variables (linear terms) | YES | YES | YES | YES | YES | YES | YES | YES | YES | YES | YES | YES | YES |
| Control variables (quadratic terms | YES | YES | YES | YES | YES | YES | YES | YES | YES | YES | YES | YES | YES |
| Constant | −0.0587 | 0.166 | 0.0453 | 0.0330 | 0.0811 | 0.102 | 0.0497 | 0.0827 | −0.0117 | 1.003 *** | 1.792 *** | 2.208 *** | 0.782 ** |
| | (0.158) | (0.131) | (0.110) | (0.162) | (0.129) | (0.115) | (0.135) | (0.113) | (0.162) | (0.251) | (0.323) | (0.306) | (0.292) |
| N | 180 | 180 | 180 | 180 | 180 | 180 | 180 | 180 | 180 | 162 | 108 | 198 | 54 |

Standard errors in parentheses, * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$.

Geographic location heterogeneity: The policy impact of land transfer varies between geographic location zones, as seen in Table 6 by the regression findings of model (4). Land transfer regression coefficients in the northeast, centre, and west are all statistically significant at the 5%, 10%, and 1% levels of significance, respectively. In terms of policy impact, the central area ranks first, the north-eastern and western regions rank second and third, while the eastern region ranks worst. Potential causes of regional diversity include a weaker land transfer impact and lower marginal returns to policy in the east, an area with high levels of urban–rural integration. Much of the land transfer policy's impact has been felt in the central area, which is now experiencing fast integration and growth. Inadequate infrastructure and a bad market environment restrict the policy's impact in the western area, despite its large impact. There is more room for land transfer policies and more power in the northeast, an area with plenty of undeveloped land.

### *4.6. Further Discussion*

The study challenge in this work is better addressed by dual machine learning, which offers distinct benefits in variable selection and model estimates compared to standard causal inference models [70]. First, there are a lot of societal and economic elements that influence urban–rural integrated development; second, limiting the influence of these other factors is important for accurately estimating the benefits of policies. However, conventional regression models run the risk of encountering the "curse of dimensionality" and multicollinearity when working with control variables that have a high degree of dimension, casting doubt on the reliability of the estimates. By utilising multiple machine learning techniques and their regularisation algorithms, dual machine learning can automatically screen a set of high-dimensional control variables that have already been selected. This process yields a set of control variables that are both effective and predictively accurate, thereby avoiding the "curse of dimensionality" and the biased estimation problem that arise from having too few main control variables [71]. Conversely, nonlinear relationships between variables are common in economic transformation and growth. Traditional linear regression methods can introduce bias into model setting and provide insufficiently robust estimations. To circumvent this issue of model misspecification, dual machine learning takes advantage of the machine learning algorithms' proficiency in handling nonlinear data [30]. Dual machine learning, which is based on the concepts of instrumental variable functions, two-stage prediction residual regression, and sample split fitting, may also guarantee the unbiased estimate of disposal coefficients in small samples and relieve the "regularity bias" in machine learning estimation [31,72].

This paper analysed the impact of land transfer on urban–rural integrated development using a continuous Difference-in-Differences (DID) model to validate the efficacy of dual machine learning models in causal inference analysis. Table 7 presents a comparison of the regression outcomes of the dual machine learning model (DML) and the double difference model (DID) across various combinations of provincial effects, fixed effects, and control variables, while Figure 2 illustrates the results of the parallel trend test for the DID model corresponding to different scenario combinations.

Initially, regarding the comparison of robustness and significance, the table indicates that the coefficients of the explanatory variables in DML exhibit greater significance and smaller standard errors across all six strategies. Furthermore, the coefficients of DML nearly achieve the 1% significance level in all models, implying that its estimation results demonstrate enhanced robustness. Conversely, in the DID models, particularly those incorporating more complex control variables (e.g., Strategies 4, 5, and 6), the coefficients for the explanatory variables LAND$*$$I_t$ exhibit reduced significance and, at times, negative values (e.g., in the DID models of Strategies 3, 4, 5, and 6). This observation may suggest

that the DID framework is capturing instability in managing the intricate relationships involved. This is likely due to DML's capability to model high-dimensional covariates and nonlinear relationships using machine learning algorithms, which effectively eliminate confounding bias and yield more accurate treatment effect estimations. The DID model is based on linear assumptions that fail to sufficiently account for nonlinear and interaction effects of high-dimensional covariates, potentially resulting in bias [29,30,73].

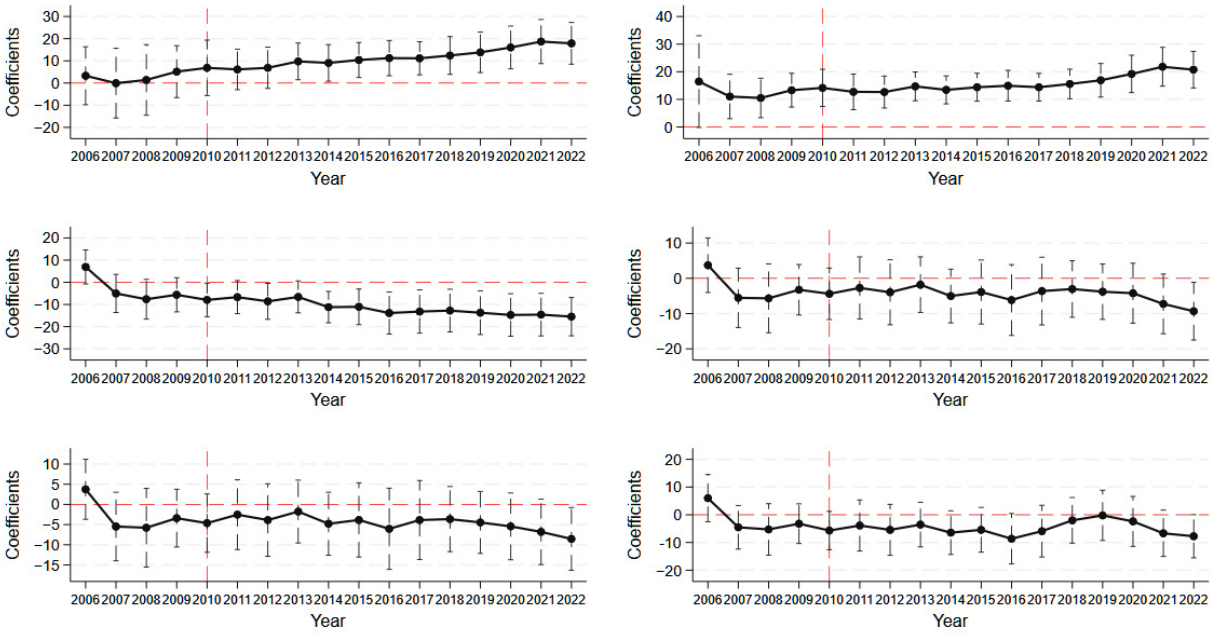



**Figure 2.** Summary of parallel trend test for double difference model.

Secondly, the comparison in complex settings, including the control for fixed effects and high-dimensional control variables, reveals that in Strategy 4 (which accounts for province effects, time effects, and the primary term of the variable), the coefficient of DML is 4.059 ***, indicating significance and a reasonable direction. In contrast, the coefficient of DID is −3.131, exhibiting low significance and a direction inconsistent with theoretical expectations. In Strategies 5 and 6, which involve adding quadratic terms and all terms of the control variable, the coefficients of DML maintain significance (e.g., 4.568 *** and 4.044 ***), aligning with economic theory. Conversely, the coefficients of DID are predominantly negative in these complex contexts (e.g., −3.283 and −3.334), reflecting a reduction in significance and suggesting a poor fit to the complex model. The potential explanations for this are that DML employs machine learning algorithms, such as Random Forest and LASSO, that can automatically model high-dimensional and complex nonlinear relationships. The DID model is based on traditional regression, which struggles with high-dimensional data and nonlinear terms and is prone to errors in modelling setup [29,73,74].

Third, DML coefficients are always positive and highly significant across methods (e.g., adding fixed effects or high-dimensional variables), demonstrating resilience to model configuration. In contrast, DID estimation results are highly sensitive to model setting, and coefficients fluctuate substantially under different methods, even becoming negative in Strategies 3, 4, 5, and 6, which is clearly not in accordance with theoretical expectations. DML's machine learning technique may reduce the model setting mistakes' disproportionate impact on results through cross-validation and regularisation. DID relies too much on linear settings, and model instability is greater [28,29].

**Table 7.** Comparison of the regression results of the double machine learning model and the double difference model.

| | (1) | | (2) | | (3) | | (4) | | (5) | | (6) | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Variables** | **DML** | **DID** | **DML** | **DID** | **DML** | **DID** | **DML** | **DID** | **DML** | **DID** | **DML** | **DID** |
| $LAND_i * I_t$ | 13.231 *** | 13.181 *** | 14.978 *** | 14.477 *** | 8.585 *** | −11.588 *** | 4.059 *** | −3.131 | 4.568 *** | −3.283 | 4.044 *** | −3.334 |
| | (1.196) | (3.599) | (0.940) | (2.554) | (1.203) | (3.188) | (0.939) | (3.182) | (0.968) | (3.182) | (0.932) | (3.138) |
| Provincial fixed effects | NO | NO | YES | YES | YES | YES | YES | YES | YES | YES | YES | YES |
| Year fixed effects | NO | NO | NO | NO | YES | YES | YES | YES | YES | YES | YES | YES |
| Control variables (linear terms) | NO | NO | NO | NO | NO | NO | YES | YES | NO | NO | YES | YES |
| Control variables (quadratic terms) | NO | NO | NO | NO | NO | NO | NO | NO | YES | YES | YES | YES |
| Constant | 0.010 | 61.324 *** | −0.018 | 61.029 *** | 1.591 *** | 66.955 *** | −0.000 | 101.109 *** | 0.004 | 80.410 *** | 0.005 | 11.112 |
| | (0.204) | (1.040) | (0.154) | (0.581) | (0.177) | (0.725) | (0.082) | (10.343) | (0.083) | (5.253) | (0.082) | (32.142) |
| R-squared | | 0.242 | | 0.630 | | 0.865 | | 0.901 | | 0.904 | | 0.912 |
| Observations | 540 | 540 | 540 | 540 | 540 | 540 | 540 | 540 | 540 | 540 | 540 | 540 |

Robust standard errors in parentheses, *** $p < 0.01$.

Fourth, the DML model's robustness makes it better for describing the economic mechanism of rural land system reform on urban–rural integration development. After controlling for high-dimensional confounders, the DML model demonstrates that land system reform positively affects urban–rural integration development (significant positive coefficients in Strategies 4, 5, and 6). This shows that land system reform may have encouraged urban–rural integration by optimising land resource allocation and rural economic development. DID results are challenging to explain mechanistically due to their poor significance and variable direction. Most obviously, from the graph of the parallel trend test results of the DID model, under most strategies (especially Strategies 3 and 4), the treatment group and control group trends before the policy implementation are not parallel, which may violate the parallel trend assumption of DID. This suggests systematic bias in DID estimates. Instead of using parallel trends, the DML approach directly predicts treatment effects by correcting for confounders using a machine learning model [28–30,73].

## 5. Conclusions, Discussion and Implications

### *5.1. Main Conclusions of This Study*

From the standpoint of factor mobility, land system innovation ensures urban–rural integrated development. This study employs a machine learning causal inference method to examine the effects of land system reform on urban–rural integrated development, set against the backdrop of the official liberalisation of the land transfer policy in 2010, utilising Chinese provincial-level data from 2005 to 2022. The research indicates that the execution of the land transfer policy significantly enhances urban–rural integrated development, particularly in fostering economic, ecological, and demographic integration between urban and rural areas, a conclusion supported by various robustness tests. The heterogeneity test reveals significant differences in the policy effects of land transfer across regions characterised by varying levels of urban–rural integration and development, exhibiting a marginal decreasing trend. Similarly, the policy effects of land transfer across regions with differing levels of land transfer also demonstrate a marginal decreasing trend. Furthermore, the impact of land transfer on urban–rural integration displays a nonlinear trend influenced by different levels of economic development, with the most pronounced effects observed in regions with medium levels of economic development. The impact of land transfer policies varies across geographic regions, exhibiting the most significant effects in the central region, followed by the northeast, west, and least in the east region. The mechanism test indicated that reforming the rural land system facilitates the integrated development of urban and rural areas by promoting agricultural "double-scale" operations, fostering new business entities, transferring rural labour, and enhancing agricultural capital.

### *5.2. Discussion of This Study*

The reform of the land system is an essential instrument for advancing urban–rural integrated development. The principal findings of this work align with known studies, indicating that land transfer can substantially enhance urban–rural integrated development. This article identifies a policy lag effect, contrasting with existing studies, and reveals that the land transfer policy does not significantly enhance urban–rural spatial and social integration in the sub-dimensional analysis [6,11,21,22,36]. While implementing land reform, it is important to keep in mind the policy's negative impacts and that the particular program requires constant improvement in practice; furthermore, land reform is not a silver bullet for the urban–rural imbalance problem [21]. In order to address the limitations of conventional models in causal inference and provide more solid research findings, this article presents a novel dual machine learning model for analysis, which outshines earlier works. Additionally, the policy of land transfer facilitates the transfer of rural surplus

labour, the development of new management subjects, the strengthening of agricultural capital, the promotion of large-scale agricultural management, and the two-way flow and multidimensional integration of "people, land, and money" between rural and urban areas.

Despite the fact that this study employed a dual machine learning approach for causal inference, the model's generalizability and the results' extrapolation may be impacted by the notable regional variations among Chinese provinces with respect to economic development, policy implementation, land system, and sociocultural elements. In the section on heterogeneity analysis, for instance, the study identifies notable variations in the policy effect sizes in the east, centre, west, and northeast. In actuality, China has enacted a number of land system reforms, including the "separation of three rights", in addition to the official liberalization of "land transfer" in 2010. The various mechanisms by which these policies support urban–rural integrated development require more research. Future research must be more thorough. Future research should concentrate on how various land system reforms and geographical areas affect urban–rural integration and the long-term policy dynamics involved.

### *5.3. Policy Implications of This Study*

This paper presents the following policy recommendations based on the aforementioned findings:

Firstly, the reform of the rural land system must be sustained and intensified. The reform of the land system is a crucial catalyst for advancing the integrated development of urban and rural regions in China. The Chinese government must consistently uphold the fundamental principle of "protecting the legitimate land rights and interests of farmers transitioning to urban areas while fostering voluntary and compensated transfers in accordance with the law" and persist in facilitating the systematic transfer of land. The reform of market-orientated land allocation should be further intensified, allowing the market to play a key role in the distribution of land resources. This will mitigate the issues of irrational land resource allocation and poor land utilisation rates, consequently facilitating large-scale agricultural operations, efficient rural labour transfer, and enhancing support for urban–rural integration. The reform of the rural land system should be advanced with consideration to varying urban–rural integration, economic development levels, and natural geographic characteristics, adhering to local circumstances and caution. The efficacy of the land transfer policy differs markedly across regions, suggesting that land system reform should be advanced in accordance with local circumstances, including the foundation for urban–rural integration, economic development levels, and natural geographic conditions.

Secondly, persist in advocating for extensive agricultural enterprises. To facilitate urban–rural integration, it is essential to reduce the income disparity between urban and rural inhabitants. This necessitates the exploration of agricultural transformation and enhancement, alongside supporting large-scale operators in technological innovation, capital management, and operational improvement, thereby advancing agricultural intensification and large-scale operations.

Thirdly, persist in advancing the development of new farm management entities. Motivate farmers to convey land to emerging agricultural management entities, including family farms and leading agricultural enterprises, via mechanisms such as land trusteeship, exchange, transfer, subcontracting, and leasing, to facilitate the sustained operation of agricultural land, achieve moderate-scale agricultural practices, enhance farmers' income, diminish the urban–rural income disparity, and foster the integration of urban and rural development.

Fourthly, it should persist in advancing the urbanisation of the agricultural migrant population. The Chinese government must protect the lawful land rights and interests of

urban migrant workers in compliance with legal standards, establish a mechanism for the lawful withdrawal of land contracting rights from the agricultural migrant population, executed voluntarily and with compensation, and persist in enhancing the assurance system for the equal provision of basic public services to the agricultural migrant population, thereby advancing the integrated development of urban and rural regions.

Fifthly, consistently advance the enhancement of agricultural capital. The Chinese government should fully leverage the financial characteristics of land operation rights, enhance the financing mechanisms for rural land property rights by utilising these rights to explore innovative inclusive rural finance models, and advance the deepening of agricultural capital. This will facilitate the transfer and assimilation of surplus agricultural labour, ultimately achieving the integration of urban and rural development.

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