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Environmental regulations or expected revenue: What plays a more important role in China's green transition of agriculture?

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Abstract: Policy constraints and market incentives have made it an important foundation for developing countries such as China to develop agricultural green transition policies. This study employed the panel data of 31 provinces in China from 2003 to 2022 and the three-dimensional framework of 'institutions, technology, and marketisation' to probe whether environmental regulation constraints or expected economic revenue incentives play a critical role in China's current agriculture development. Whether the green transition of agriculture depends on environmental regulatory policy constraints and expected economic revenue incentives is related to the level of agricultural technology development and market development. Technology and market play a positive role in the agricultural green transition by enabling the realisation of agricultural green production and the realisation of the agricultural green market.

Keywords: green market realisation capability; green production realisation capability; green total factor productivity; market failure

Agricultural green transition is a systematic transformation with a focus on production. However, production cannot be separated from the product market because the intrinsic motivation of green products comes from the expected incentives of mature markets. Therefore, the agricultural green transition includes the realisation of green production and the realisation of a green market. From the perspectives of the market and the government, a mature and sound market can achieve the benefits of green agricultural products. China has made remarkable achievements in market-oriented reform. After the founding of the People's Republic of China in 1949, a strictly planned economic system was implemented and commodities were distributed and provided according to the government's plan. Since China's reform and opening up in 1978, it has gradually reformed rural and agricultural markets and relaxed restrictions on market transactions across regions, including transactions of staple crops. In 2003, China promulgated the rural land con-

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tract law, which confirmed the right of land transfer. In 2005, China standardised land leasing activities. Consequently, labour mobility was relaxed, farmers were able to migrate to cities for nonagricultural employment, and the division of labour and specialisation of rural families were further highlighted, which promoted land transfer and the improvement of agricultural productivity. The continuous development of agricultural commercialisation has become the main direction of China's agricultural market reform. With continuous urbanisation in China, higher green development requirements are put forward for commercial agriculture.

However, China's current agricultural green commercial market is developing slowly due to high transportation costs, few intermediary markets, asymmetric information, and lack of market credit preventing it from achieving 'high quality and high price' (Reganold and Wachter 2016). Thus, the 'lemon market' appears (Akerlof 1978). Smith (2002) argued that when the market fails, the government should be more effective. The government should issue relevant regulations or incentive policies, such as environmental regulations and other policy measures, to stimulate the positive external behaviour of protecting the ecological environment in agricultural production, promote the internalisation of pollution costs in agricultural production through mandatory constraints, and avoid the market failure (Kallio et al. 2019; Cui et al. 2022; Guo et al. 2022). Relevant environmental policies have played an essential role in the early stage of green agricultural development, especially when there is market failure or immature market development (Lu et al. 2020). In addition, the marketisation of land and other factors, along with the market-based trading of agricultural products, can enhance the prices of premium agricultural goods. Essentially, the advancement of green agricultural technology and the redistribution of resources have promoted the improvement of agricultural green total factor productivity (Lu et al. 2020; Zhang, 2021; Castilo-Díaz et al. 2023). Related research consistently indicates that environmental policies and the incentives for expected revenue achievable through market mechanisms fundamentally drive and stimulate advancements in green technology and the reallocation of resources, thus advancing the green transition of agriculture (Cui et al. 2022; Boix-Fayos and De Vente 2023; Ouyang et al. 2023; Agrawal et al. 2024).

Numerous studies exist on the green transition of agriculture; however, research from the perspective of farmers' micro-psychological expectations remains limited.On the one hand, we need to understand the micro-psychology of farmers engaging in agricultural green production from a market-oriented perspective, aiming to endogenously address the issue where farmers possess the capability but lack the willingness to engage in green agricultural production. On the other hand, we must explore the scenario where farmers possess the willingness but not necessarily the capability for green agricultural production, taking into account the level of technological advancement. Specifically, only when farmers possess both the willingness and capability for green agricultural production can agricultural green transition be achieved. The development of such agricultural green production activities requires further research on the role played by environmental regulations (institutions), green production realisation capability (technology), and green market realisation capability (marketisation).

The main contributions of this study are as follows: *i*) We explored whether environmental regulations or expected revenue incentives play a more important role in the agricultural green transition of developing countries like China, and probed the applicable scenarios of agricultural environmental policies, that is, how to implement environmental policies at different stages of technology and market development, such as what environmental policies are applicable and their intensity of implementation. All countries have implemented various policies over the past ten years, but due to 'less success and more failure,' scholars now focus on how to implement them rather than on whether they should be implemented. (Aghion et al. 2016). The conditions under which expected revenue incentives play a role in the agricultural green transition under different levels of technology and market development were also revealed; and *ii*) based on the lemon market theory, we constructed a three-dimensional framework of 'institutions, technology, and marketisation,' which involves environmental regulations, the realisation capability of green production, and market green revenue, and analysed whether environmental regulatory policy constraints or expected economic revenue incentives play a significant role in the green transition of agriculture in the different development stages of technology and market.

Theoretical framework

Environmental regulation constraints and agricultural green transition. There is a strong need for environmental regulation constraints in the agricultural green transition. Based on the versatility of agri-

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culture, environmental regulation constraints lay a realistic foundation for coordination between ecological environment and economic revenue to ensure that the market can effectively use social resources (natural capital and public funds) and generate good production results (high-quality agricultural products) and non-commodity functions (ecological environment) (Hector and Bagchi 2007; Kiefer et al. 2019; Du et al. 2024). Due to the high risk in the early stage of the green agricultural transition and the problematic identification of agricultural product quality due to information asymmetry in the market, the value of green agricultural products could not be fully realised. As a result of market failure, a large number of chemical fertilisers and pesticides are applied. The main reason may lie in the division of agricultural production processes and adverse selection of farmers, which aggravate the deterioration of the agricultural environment. Environmental regulations could promote the internalisation of pollution costs in agricultural production through mandatory constraints, reduce the externality of production and consumption behaviour, and address the lemon market problem in agriculture (Akerlof 1975; Anissa et al. 2021).

Environmental regulations are also significant in the green transition of agriculture. Relevant studies argue that environmental regulations have a resource allocation effect during agricultural production (De Santis et al. 2021). Due to the varying resources possessed by farmers and their distinct developmental stages, environmental regulations exert asymmetric impacts, thereby facilitating the redistribution of resources. (Tombe and Winter 2015). Specifically, environmental regulations exhibit a compliance cost effect. Neoclassicism argues that the compliance cost of environmental regulations would crowd out individual resource investment and limit investment in technological innovation (Gray and Shadbegian 2003; Johnstone et al. 2017; Nelson and Phillips 2018). However, environmental regulations also exhibit an innovation compensation effect. Faced with costs associated with environmental regulations, farmers are more willing to adopt new technologies and update production equipment and methods (Porter and Linde 1995; Bekun 2024).

In the marketing stage of agricultural production, environmental regulation constraints bring mandatory legal constraints such as the promulgation of relevant agricultural green production laws, formulation of agricultural production quality standards, and establishment of a corresponding punishment mechanism for violations of the laws. The government would establish legal protection for production, distribution, and sales. If farmers have confidence in the realisation of green agricultural production through the market, they will generate endogenous incentives and carry out green production behaviour (Brunnermeier and Cohen 2003; Lena et al. 2022). However, environmental policy constraints promote the realisation of agricultural products' revenue by eliminating information asymmetry, such as product information disclosure, green product certification, and the recent rise of e-commerce live streams in China, which could increase consumers' trust in green agricultural production and avoid the appearance of a lemon market. Then farmers could achieve 'high quality and high price' and generate internal incentives to implement green production behaviour (Greenstone et al. 2012; Khan and Ulucak 2020).

Expected revenue incentives and agricultural green transition. Institution, technology, and marketisation are three essential elements in economic transition. According to the theory of rational expectation, the public would fully use available information to make rational predictions and judgments. As for the green transition of agriculture, farmers would also have rational expectations for the realisation of expected revenue, including judging their own green production realisation capability (technology) during production and green market realisation capability (marketisation) after production.

According to a rational individual's assumption, farmers adjust their decisions according to the expected revenue of agricultural products, that is, whether to implement green behaviour. The basis for decision-making is to evaluate whether they have green production capability. Specifically, farmers would evaluate the technology involved in agricultural green production based on their past production experience or whether they could obtain the technology. If they have agricultural green production technology or ways to obtain it by learning, the green production behaviour of farmers has internal incentives. During green agricultural production, green production processes could effectively promote the green transition of agriculture (Jaffe and Palmer 1997). On the one hand, expected revenue incentives could force the adjustment of factor input structure and promote centralised land transfer and labour flow. In addition, market-based allocation of the factors of production could effectively promote resource allocation and improve production technology. On the other hand, according to resource-based theory, when farmers obtain revenue from green production, they could update production equipment,

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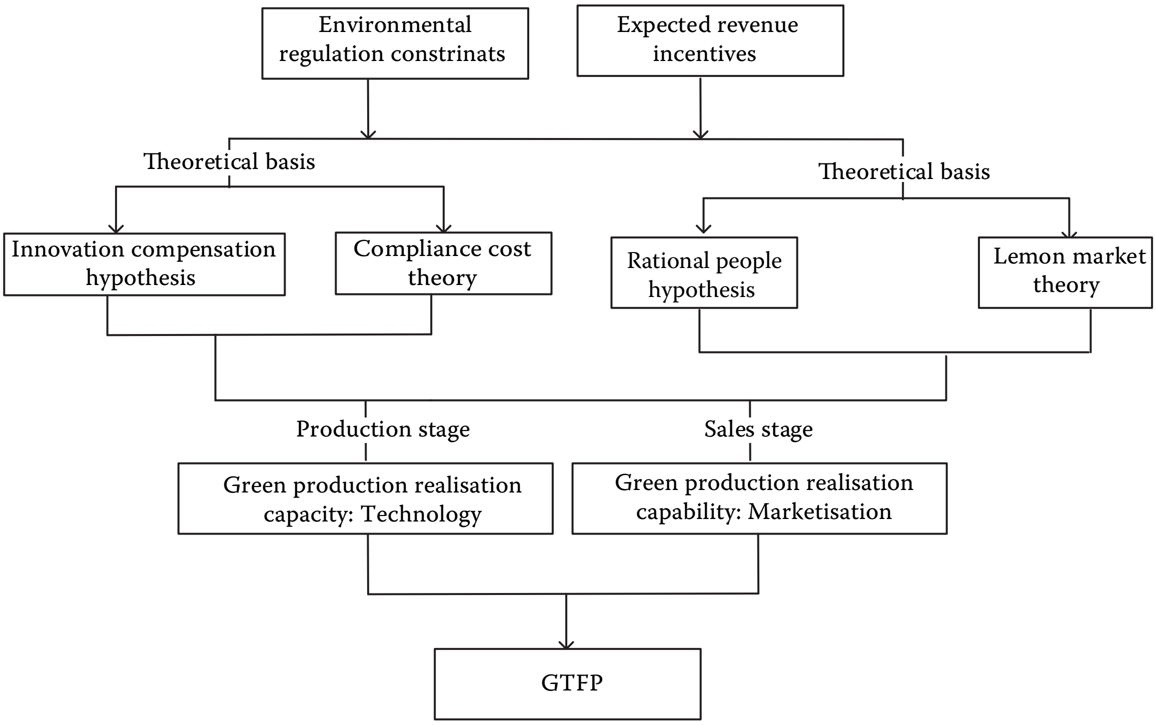

Figure 1. Theoretical framework of this study

GTFP – green total factor productivity
Source: Authors' own elaboration

and production technology in the production process, which would positively impact the green transition of agriculture.

The theoretical framework of the study is illustrated in Figure 1.

Even with green production capability, farmers may not desire green production. This desire may materialise only when they are convinced that agricultural products could obtain expected revenue through the market. When the market is well developed or mature, Karl Marx's law of value comes into play, which states that through the supply and demand mechanism and price and competition mechanism in the market, the product's price would match its value. Green agricultural production could obtain corresponding revenue through an effective market, which has an internal incentive for farmers' green production behaviour (Reganold and Wachter 2016; Kallio et al. 2019). On the one hand, farmers could obtain green revenue through the market, which indicates that the agricultural market is relatively sound, thereby reflecting the reduction of government subsidies. For example, the excessive use of chemical fertilisers in China is strongly associated with government subsidies (Wang et al. 2022). On the other hand, endogenous incentives to farmers by expected revenue could prompt the spread of environmental standards and green technologies, improve the credit commitment system of market participants, and increase the market's power to determine the price of agricultural products (Zhang et al. 2021).

MATERIAL AND METHODS

Using the agricultural panel data of China's provinces from 2003 to 2022, this study investigated the impact of government environmental regulations and market revenue incentives on the green transition of agriculture. The White test showed no significant variance, the Dickey-Fuller test showed stationarity and no autocorrelation, and the variance inflation factor (*VIF*) test showed no multicollinearity. Therefore, the OLS regression model was employed.

$$GTFP_{it} = \alpha + \beta_1 ER_{it} + \beta_2 L.Exp_{it} + \beta_3 Z_{it} + \xi_{it} \quad (1)$$

where: $GTFP_{it}$ – green development of agriculture; ER_{it} – environmental regulations, which is divided into command control environmental regulations (*CCER)* and market incentive environmental regulations (*MIER*); $L.Exp_{it}$ – expected revenue of agriculture (the basis

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for determining the expected revenue of the previous period was based on the revenue of the current period, therefore, a lagged period was adopted to represent the expected revenue); *Z* – control variable, which includes financial support (*Fin*), technical development (*Tec*), economic development (*Eco*), and natural disasters (*Dis*); *i* – industry; *t* – time; ξ – random error term.

The variables were defined as follows:

Dependent variable. The green development of agriculture was denoted by green total factor productivity (*GTFP*). Agricultural *GTFP* is productivity that can reflect the constraints of resources and the environment. Furthermore, it can better reflect the coordinated development of agricultural production and environmental protection. Along with China's current requirements for agricultural production environments, this study considers factors such as water resources, environmental pollution, and carbon emissions, especially the carbon emissions generated by agricultural non-point source pollution, and the cross-influence of various production factors as unexpected output factors.

We adopted the hybrid distance function model (EBM function) proposed by Tone and Tsutsui (2010), encompassing both radial and non-radial distance functions. We utilized the EBM function to calculate agricultural *GTFP*.

Independent variable. Based on existing research and data availability, this study determined environmental regulation variables as follows:

i) Agricultural command control environmental regulation (CCER) policy, denoted by the product of the number of environmental regulatory policies implemented at the provincial level and relative emissions of agricultural pollution within a given year. The relative emissions of agricultural pollution include total nitrogen (*TN*), total phosphorus (*TP*), pesticide residues, and agricultural film residues produced by fertilisers treated using the entropy method. This measurement method can accurately embody the actual situation of agricultural administrative order-type environmental management. The method uses environmental constraint policies to measure the regional pollution level and considers the relative emissions level of pollution, thereby reducing the problem of inaccurate measurement caused by only measuring the quantity of environmental policies and avoiding the problem of additional environmental policies issued in heavily polluted regions.

ii) According to whether the provincial carbon emissions trading market is launched, the variable value was 1 after the launch of the carbon emissions trading market and 0 before the launch. It was then multiplied by the relative emissions of CO_2. The variable denoted *MIER*, which effectively reflected whether the carbon market is established and the impact of carbon market trading on CO_2 emissions. This measurement method considers the carbon market and CO_2 emissions and accurately reflects the actual situation of market-oriented environmental policy constraints.

The expected revenue of agricultural production (*Exp*) was denoted by the number of green certifications for agricultural products. The number of green certifications refers to the production environment, production technology, product quality, packaging, storage, and transportation of agricultural products that comply with national standards and regulations. Generally speaking, the greener certifications there are for agricultural products, the higher the revenue. Especially in the context of China's underdeveloped agricultural market and the need for environmental regulations, using this variable is reasonable.

Control variables. *i*) Financial support (*Fin*) was denoted by the proportion of fiscal expenditure on agriculture, forestry, and water affairs in the general budget expenditure and was used to measure the national policy incentive for agricultural development, which was derived from China Rural Statistical Yearbooks (Rural Social and Economic Survey Department of the National Bureau of Statistics 2023). *ii*) Technical development (*Tec*) was denoted by the sum of invention patents, utility model patents, and appearance design patents of 'agriculture', which was derived from China National Knowledge Infrastructure (CNKI 2023) and collected manually. *iii*) Economic development (*Eco*) was denoted by the disposable revenue of rural residents. The data came from two different sources. Due to missing data, rural residents' per capita disposable revenue was measured from 2013 to 2022, and the remaining data was replaced by the per capita net revenue of rural households from 2003 to 2012. From the perspective of data change trends, there was a certain degree of continuity, thereby making this replacement feasible, and they originated from China Rural Statistical Yearbooks. *iv*) Natural disasters (*Dis*) were denoted by the proportion of affected area in the total sown area of crops, which reflects the influence of uncontrollable climate factors, and it is from China Rural Statistical Yearbooks (Rural Social and Economic Survey Department of the National Bureau of Statistics 2023). *v*) Marketisation development (*Marketisation*), according to the production and distribution characteristics of agriculture, includes factor (*Factor_mar-*

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ketisation) and product marketisation (*Product_marketisation*). Product marketisation was denoted by 'the degree to which the price is determined by the market' and 'reducing local protection in the commodity market.' Factor marketisation mainly included 'human resource supply conditions,' 'marketisation of technological achievements,' and 'marketisation of the financial industry', which are from China Provincial Market-Oriented Index Report (Wang et al. 2021) issued by the China National Economic Research Institute. Regularly updated data is published in the China Market-Oriented Index Database. The index comprises subindicators, such as the development degree of the factor and product markets and the relationship between the government and market, which are derived from statistical or enterprise survey data. In addition, some missing data was filled in using the difference or moving average method.

RESULTS AND DISCUSSION

Depending on data availability, 31 provinces, autonomous regions, and municipalities (excluding Hong Kong, Macau, and Taiwan) of China were selected as the research sample from 2003 to 2022. In 2003, the Third Plenary Session of the 16th Central Committee of the People's Republic of China comprehensively elaborated upon and promoted the implementation of the scientific outlook on development, thereby including the environment into the official performance appraisal system and urging local governments to formulate environmental policies. Based on data availability, our research deadline was 2022.

The average *GTFP* of agriculture measured by the EBM method was 0.670, indicating that the *GTFP* of agriculture was low as a whole, and the mean value of expected revenue (*Exp*) was 4.925. The mean value of *CCER* is 1.161, with a maximum of 18, indicating that the Chinese government issued environmental regulations yearly at the provincial level. The mean value of *MIER* was 0.106, which means market-intensive environmental regulations were still low in China (Table 1).

Benchmark regression

This section empirically analyses the impact of environmental regulations and expected revenue incentives on the green transition of agriculture and compares the differences between the two environmental regulation tools. Estimation results are reported in Table 2. Columns 1–4 are the results of basic regressions, and columns 5–8 are the results of endogenous regressions. For the green transition of agriculture, *CCER* and *MIER* positively impacted agricultural *GTFP*, and both had a positive impact on green transition at a significance level of 5%, which is consistent with the innovation compensation theory. Compared with *CCER*, *MIER* played a more significant role in the green transition of agriculture, thereby reflecting that it has formed a strong constraint on agricultural productive pollution factors and mode of production through carbon emissions trading. From the input of agricultural factors to the deep processing of products, environmental reg-

Table 1. Descriptive statistics of variables

Variable	Mean value	SD	Minimum	Maximum	No. of observations
CCER	1.161	1.759	0.000	18.000	620
MIER	0.106	0.308	0.000	1.000	620
Exp	4.925	1.426	0.000	0.807	620
Tec(log)	4.601	1.813	0.000	10.000	620
GTFP	0.670	0.286	0.134	1.118	620
Fin	0.105	0.043	0.012	0.231	620
Eco(log)	8.982	0.748	7.355	10.727	620
Dis	0.203	0.148	0.000	0.886	620
Marketisation	6.423	2.208	1.420	11.710	620
Factor_marketisation	5.543	2.929	1.129	15.870	620
Product_marketisation	7.794	1.506	1.460	10.610	620

CCER – command control environmental regulation; *MIER* – market incentive environmental regulations; *Exp* – expected revenue of agricultural production; *Tec(log)* – after taking the logarithm of technical development; *GTFP* – green total factor productivity; *Fin* – financial support; *Eco* – economic development; *Dis* – natural disaster

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ulations play the role of legal constraints, including the formulation of production standards, disclosure of origin place information, and other measures. Overall, environmental regulations could address the problems of market failure or the lemon market of agricultural production to a certain extent. The expected revenue significantly promoted the green transition of agriculture; this impact was much greater than that of regulatory constraints. The possible reason is that farmers comply with the assumption of economically rational people in the production process (Zhang 2021). Compared with nongreen production, green production can bring higher revenue, which can affect farmers' green production decisions and behaviours. The green transition of agriculture has been realised from the aspects of green factor input, production process, and warehousing and distribution, which is also consistent with the research conclusions of Yang et al. (2017).

Endogeneity regression

In the benchmark regression, the green development of agriculture and market revenue may have endogeneity problems such as reverse causality, variable measurement error, and variable omission, that is, after green transition, agricultural market revenue would rise. Meanwhile, farmers also have the capability or willingness to promote the green transition of agriculture. Therefore, columns 5–8 of Table 2 present test results after using the instrumental variable method. Under limited sample conditions, system generalised method of moments (SYS-GMM) had a smaller estimation bias than difference generalised method of

Table 2. Benchmark regression and endogenous regression results

Variable	OLS (1)	OLS (2)	OLS (3)	OLS (4)	IV (5)	IV (6)	IV (7)	IV (8)
CCER	0.002*** (6.403)	–	–	0.002*** (3.374)	0.009** (2.250)	–	–	0.005** (2.320)
MIER	–	0.066*** (4.023)	–	0.063*** (4.055)	–	0.072** (2.025)	–	0.097** (2.453)
L. Exp	–	–	0.206*** (4.021)	0.207*** (5.903)	–	–	0.324** (2.226)	0.225** (2.521)
Tec	0.176*** (6.455)	0.160*** (6.336)	0.160*** (3.997)	0.157*** (5.352)	0.173** (2.397)	0.181*** (6.368)	0.178*** (8.156)	0.153*** (6.678)
Fin	0.010** (2.357)	0.012** (2.233)	0.010** (2.366)	0.011** (2.272)	0.013*** (5.375)	0.010* (1.732)	0.000* (1.787)	0.012** (2.432)
Eco	0.000*** (3.300)	0.000*** (3.504)	0.000*** (3.551)	0.000*** (3.270)	0.000 (0.178)	0.001** (2.011)	0.000 (1.220)	0.000 (0.043)
Dis	–0.064* (–1.701)	–0.060 (–1.612)	–0.076** (–2.501)	–0.071* (–1.895)	0.052 (0.428)	0.152 (1.526)	0.137 (1.167)	0.046 (0.436)
EMP	–	–	–	–	0.323*** (14.236)	0.357*** (15.387)	0.334*** (13.257)	0.357*** (9.756)
Observations	620	620	589	589	558	558	558	558
Adjusted R^2	0.452	0.570	0.665	0.668	–	–	–	–
Year effect	yes	yes	yes	yes	yes	yes	yes	yes
Province effect	yes	yes	yes	yes	yes	yes	yes	yes
Sargan test	–	–	–	–	15.116 (0.002)	12.294 (0.023)	11.763 (0.025)	12.025 (0.033)
AR(1)	–	–	–	–	0.013	0.015	0.011	0.018
AR(2)	–	–	–	–	0.237	0.146	0.175	0.188

*,**,*** $P < 0.1$, $P < 0.05$, $P < 0.01$, respectively; *t*-statistics in parentheses; *OLS* – ordinary least squares; *IV* – instrumental variable; *CCER* – command control environmental regulation; *MIER* – market incentive environmental regulations; *Exp* – expected revenue of agricultural production; *Tec* – technical development; *Fin* – financial support; *Eco*– economic development; *Dis* – natural disasters; *EMP* – environmental monitoring station; AR – autoregressive model

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moments (DIFF-GMM) due to the addition of a first-order difference lag term of the dependent variable as an instrumental variable in the horizontal equation. Therefore, we used SYS-GMM for endogeneity regression. The results of the systematic SYS-GMM test show that the green transition of agriculture was easily affected by early accumulation and sustainability characteristics. In this study, the number of staff in the environmental monitoring station (*EMP*) was used as the instrumental variable, because *EMP* is highly related to environmental regulations. The more staff there are in the environmental monitoring station, the more complete the disclosure of environmental pollution information is, and the government may formulate more stringent policies. In China, environmental monitoring stations mainly monitor industrial pollution and pay little attention to agricultural pollution. Thus, the number of staff in the environmental monitoring station has little relationship with the total factor productivity of agriculture, and *EMP* is independent of the current random error term. It meets the correlational and exogenous conditions required for instrumental variables. It is verified that no problems of sequence correlation of disturbance terms and excessive identification of instrumental variables exist, and the instrumental variable is valid. The results of columns (5–8) show that the conclusion remains valid after considering endogeneity.

Heterogeneous effects

As noted in the Theoretical framework subchapter, the development mode transition involves institution, technology, and marketisation. The green production realisation capability (technology) and green market realisation capability (marketisation) are essential for the agricultural green transition. Only when farmers have green capability and willingness can the agricultural green transition have a micro-foundation. Therefore, environmental regulations and expected revenue incentives have different impacts on the agricultural green transition under different technology and marketisation. In this section, industries are divided into three subgroups, namely, high-technology (marketisation), medium-technology (marketisation), and low-technology (marketisation) according to the 1/3 and 2/3 quantiles to obtain detailed conclusions.

Green production realisation capability (technology). Environmental regulations show significant differences among the subgroups with different technological development. The impact of environmental regulations on the agricultural green transition shows positive, no, and negative effects in high-, medium-, and low-technology regions, respectively. Thus, resulting from the compliance cost effect and innovation compensation effect, high-technology regions have high technology to reduce environmental pollution and avoid the cost of environmental regulations. For medium-technology regions, the impact of environmental regulations is insignificant, which may be due to the offset of compliance cost effect and innovation compensation effect, the positive impact of technology has not yet emerged. However, low green technology capability exists in low-technology regions, and environmental regulations only bring

Table 3. Classified inspection according to technical development

Variable	(1) High-tech	(2) High-tech	(3) Medium-tech	(4) Medium-tech	(5) Low-tech	(6) Low-tech
CCER	0.006* (1.656)	0.004*** (2.824)	0.001 (1.303)	0.000 (1.415)	–0.002*** (–5.413)	–0.003*** (–6.587)
MIER	0.011** (2.131)	0.075*** (4.367)	0.008 (0.877)	0.005 (0.253)	–0.012** (–2.346)	–0.123** (–2.352)
L.Exp	–	0.082*** (5.132)	–	0.052** (2.536)	–	0.004** (2.257)
Control variables	yes	yes	yes	yes	yes	yes
Year effect	yes	yes	yes	yes	yes	yes
Province effect	yes	yes	yes	yes	yes	yes
Adjusted R^2	0.489	0.510	0.436	0.441	0.225	0.227
Observations	190	190	190	190	209	209

*,**,*** $P < 0.1$, $P < 0.05$, $P < 0.01$, respectively; *t*-statistics in parentheses; *CCER* – command control environmental regulation; *MIER* – market incentive environmental regulations; *Exp* – expected revenue of agricultural production

Source: Authors' own elaboration

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Table 4. Classification test according to marketisation

Variable	(1) High-pro	(2) Medium-pro	(3) Low-pro	(4) High-fac	(5) Medium-fac	(6) Low-fac
CCER	0.002** (2.221)	0.002* (1.924)	0.003* (1.912)	0.001* (1.654)	0.001* (1.687)	0.003** (2.307)
MIER	0.031*** (8.547)	0.010* (1.936)	0.001** (2.221)	0.013*** (6.172)	0.010* (1.808)	0.002* (1.873)
L.Exp	0.068*** (9.393)	0.052** (2.354)	0.040** (2.244)	0.087*** (8.835)	0.065* (1.951)	0.043* (1.896)
Control variables	yes	yes	yes	yes	yes	yes
Year effect	yes	yes	yes	yes	yes	yes
Province effect	yes	yes	yes	yes	yes	yes
Adjusted R^2	0.616	0.609	0.687	0.625	0.590	0.620
Observations	190	190	209	190	190	209

*,**,*** $P < 0.1$, $P < 0.05$, $P < 0.01$, respectively; t-statistics in parentheses; pro – product marketisation; fac – factor marketisation; *CCER* – command control environmental regulation; *MIER* – market incentive environmental regulations; *Exp* – expected revenue of agricultural production

Source: Authors' own elaboration

compliance costs, some studies have also reached similar conclusions (Guo et al. 2022). Therefore, it is imperative to design a reasonable cost-sharing mechanism for environmental regulations to help farmers overcome the burden of compliance costs. Revenue incentives positively impacted the green development of agriculture in high-, medium-, and low-technology regions. Among them, the expected revenue in high-technology regions had the greatest positive impact on the green transition of agriculture, which reflects that farmers had a realistic basis for realising thew expected revenue under high-tech agricultural development, thereby promoting the green production behavior of farmers and the green transition of agriculture (Table 3). This is also consistent with Castillo-Díaz's research conclusion (Castillo-Díaz et al. 2023).

Green market realisation capability (marketisation). As Table 4 shows, compared with factor marketisation, product marketisation played a greater role in the green transition of agriculture. This difference indicates that production marketisation had a direct impact on farmers' revenue, which is best felt by the revenue generated by the marketisation and could also effectively force factor marketisation. Meanwhile, whether for production or factor marketisation, *MIER* played a greater role when the market was highly developed. On the contrary, *CCER* played a greater role when the market was not highly developed, which aligns with the 'two hands' proposed by Adam Smith's theory (Salahuddin et al. 2020). Therefore, it also means that market-oriented agriculture has become an essential driving force for the green transition of agriculture (Zhang et al. 2021).

CONCLUSION

This study discussed the green transition of agriculture within the analytical framework of institutions, technology, and marketisation and examined which is more critical in this green transition: environmental regulation constraints or expected revenue incentives. Furthermore, it analysed how to improve the degree of agricultural marketisation in developing countries such as China. The findings show that *i*) environmental regulations constraints and expected revenue incentives positively impacted the green transition of agriculture, and *MIER* had a greater positive impact than *CCER*. *ii*) Green production and green market realisation capabilities were the key factors of the agricultural green transition, and they played an active role through technology and marketisation in the green transition of agriculture.

This study has profound policy implications. First, the government should establish a flexible gradient functional environmental regulations policy. When the technology and market are immature, the intensity of *CCER* should be appropriately increased to promote the green transition of agriculture, on the contrary, when the technology and market are mature, the government should constantly improve the *MIER* system led by the carbon emissions trading system. Second, the

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realisation capability of agricultural green production should be vigorously cultivated from the technical perspective. This entails improving the innovation-driven environment, adjusting the research and development direction of agricultural scientific and technological innovation, orienting toward agricultural green development, improving agricultural green production capability, reducing agricultural green production costs, and building a diversified agricultural technology extension system, promoting the transformation of green agricultural scientific and technological innovation achievements. Third, the government should vigorously cultivate the realisation capability of the green market from the market perspective. The government needs to promote the development of tangible markets, such as transportation and market network organisation, and promote the market-oriented distribution of agricultural factors and production to form a large unified market. Cultivating the green market's realisation capability also entails promoting intangible markets, improving the level of agricultural market credit and intellectual property protection, standardising agricultural green market access.

Although this study considers the differential effects of environmental regulation constraints and expected economic revenue incentives in scenarios where developing countries have different levels of technological and market development, it provides a reference for the green transition of agriculture in developing countries. However, this article also has some limitations. Due to space constraints, the measurement of marketisation indicators only considers factor marketisation and product marketisation, without considering the development of intermediary organisations and legal environment, lacking a complete analysis of agricultural marketisation issues. In addition, the internal mechanism of how environmental regulation, an exogenous constraint, can shift towards expected revenue incentives, an endogenous encouragement, has not been studied, which has become an important direction for future research.

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