China Economic Quarterly International 4 (2024) 1–12

Contents lists available at ScienceDirect

China Economic Quarterly International

journal homepage: www.keaipublishing.com/en/journals/china-economic-quarterly-international

South-South cooperation and food security: Evidence from Chinese agricultural technology demonstration Center in Africa

Shen Lin [a], Jingbo Cui [b,*]

[a] Institute of World Economics and Politics/National Institute for Global Strategy, Chinese Academy of Social Sciences, China
[b] Division of Social Sciences and Environmental Research Center, Duke Kunshan University, China

ARTICLE INFO

Keywords:
South-south cooperation
Food security
Agricultural technology demonstration

ABSTRACT

Using the Chinese Agriculture Technology Demonstration Center (ATDC) in Africa as a quasi-natural experiment, we examine the causal impacts of China's aid on crop production in Africa. The data pertain to African country-by-crop panel data from 2000 to 2018. Leveraging the triple difference-in-differences method, we find that the ATDC leads to increased crop production and improved trade dependence. The positive effects are more pronounced for free-standing technical support and ATDCs operated by state-owned enterprises. Lastly, the ATDC has profound implications for local agriculture and rural development.

1. Introduction

Food security is a global issue that concerns the shared future of humanity. The 2021 Global Report on Food Crises by the Food and Agriculture Organization of the United Nations indicates a significant increase in the number of people suffering from hunger worldwide over the past five years. In 2020, the number of people affected by hunger increased to 720–811 million, with 66% facing severe food crises in Africa. Africa is the only region that suffers from regional conflicts, extreme climate, and economic recession simultaneously, leading to increased food shortages. In 2020, about 20% of the population in Africa was affected by hunger, which was more than twice that of other regions. Food security is essential for global stability and African development. The highly integrated global food supply chain is vulnerable to policy changes, economic pressures, and natural disasters. Understanding how policy and technological innovation can solve these challenges is crucial for academia and policymakers. Food security in Africa has attracted the attention of all countries, especially China, a developing country. In 2000, the China-Africa Cooperation Forum was established to assist Africa in addressing practical difficulties, strengthening the foundation of economic and social progress, and achieving sustainable development. In 2006, the Beijing Summit of the China-Africa Cooperation Forum put forward the issue of "agriculture and food security." It proposed the establishment of ATDCs for the first time. Since then, China and Africa have conducted extensive technical cooperation and exchanges on agricultural development and food security. In recent years, the United Nations Development Programme has analyzed the positive effects of some ATDCs on local food security in case studies. It is unclear how much of an impact it has had on improving food security, reducing dependence on foreign trade, and reshaping the agricultural supply chain in Africa.

In this paper, we investigate the impact of China's ATDCs on local food security. We construct country-crop panel data, including the output, trade, and value data of food crops in African countries from 2000 to 2018 and the economic data of various countries in FAOSTAT. China's agricultural aid projects in Africa are further included. The quasi-natural experimental methods, such as the triple difference-in-differences (DID) model and event-study analysis, are used to estimate the causal impact of China's ATDCs on local food

* Corresponding author.
E-mail address: jingbo.cui@duke.edu (J. Cui).

https://doi.org/10.1016/j.ceqi.2024.02.001
Received 18 December 2023; Received in revised form 29 February 2024; Accepted 29 February 2024

Liu and Wan (2018). In the first stage (1950–1979), cooperation was carried out based on the Five Principles of Peaceful Coexistence. China assisted in the creation of various large and medium-sized infrastructure and productive projects amidst its economic challenges. In the second stage (from the 1980s to the end of the 1990s), China-Africa cooperation experienced transformation after the reform and opening up. China collaborated with the United Nations Development Programme to provide technical training in African countries and promote diversification of aid sources and methods. In the third stage, which started at the beginning of the 21st century and is still ongoing, China-Africa cooperation has been institutionalized by establishing the China-Africa Cooperation Form in 2000. The primary objective of this cooperation is to help Africa overcome practical difficulties, strengthen the foundation of economic and social development, and achieve sustainable growth. So far, three summits and eight ministerial meetings have been held. In 2021, China and Africa jointly formulated the China-Africa Cooperation Vision 2035 and adopted the Dakar Action Plan (2022–2024) to build a closer community of shared future between China and Africa.

China has provided technical assistance to Africa in three stages. At first, it recognized the significance of engaging in agriculture and developed a comprehensive work plan from 2000 to 2006. The two sides improved cooperation in food security, exchange and transfer of agricultural technologies, skills, technical assistance, agricultural machinery production, and processing of agricultural and sideline products. Food security cooperation was formally established during the exploration stage by creating ATDCs from 2006 to 2012. At the 2006 Beijing Summit, China set ten characteristic ATDCs in Africa (later increased to 14) and strengthened ties within the Special Plan for Food Security framework. At the Fourth Ministerial Conference in 2009, the first item of economic cooperation was changed to "agriculture and food security." ATDCs continued to carry out crop variety breeding and cultivation and actively relied on trust funds to support South-South cooperation with African countries. Comprehensive, high-quality, and sustainable agricultural technology cooperation has been carried out during the upgrading and transformation stages from 2012 to the present. During the Fifth Ministerial Conference in 2012, China promised to support the Comprehensive African Agricultural Development Programme (CAADP) and continue playing a pivotal role as an ATDC. During the 2015 Johannesburg Summit, China improved its ATDCs, supported African countries in enhancing their agricultural production, and encouraged and assisted Chinese enterprises in investing in African agriculture. At the 2018 Beijing Summit, China committed to supporting Africa in achieving food security by 2030 and increasing the sustainability of the ATDCs. During the 2021 Eighth Ministerial Conference, both sides agreed to fully utilize the role of ATDCs and expedite the integration of technological advancements suitable for African countries' agricultural conditions.

A primary goal of China's agricultural aid to Africa is to improve agricultural technology and development capacity. China's 14 ATDCs built after the 2006 Beijing Summit focused on technological development to help African countries achieve modernization. The ATDCs demonstrate various aspects of agriculture, including production, storage, processing, and sales, and guide farmers in improving their production capacity while promoting high-yield new varieties to recipient countries. The Chinese government, recipient governments, and China's enterprises jointly participate in ATDCs, forming a unique management structure that features both public service departments and enterprises (Li et al., 2017). The operation of ATDCs is divided into three stages: infrastructure construction lasting 1–2 years, followed by three years of technical cooperation, and 3–7 years of sustainable development and commercial operation. From 2006 to June 2011, China established Africa's first batch of 14 ATDCs. Agricultural business entities undertake each project's operation and management in the operation mode, and all ATDCs have entered the stage of technical cooperation. The ATDCs are concerned about the demand for agricultural technology cooperation in the Comprehensive African Agricultural Development Programme when providing practical agricultural technology services. The ATDCs collaborate to research and develop new crop varieties, technologies, and equipment appropriate for African conditions. As per China's Ministry of Agriculture and Rural Affairs statistics, by the end of 2018, China attempted to cultivate over 300 crop varieties in Africa and trained more than 500 practical technologies, which benefited approximately 1 million small-scale farmers.

2.2. Variation features of the ATDCs

The implementation of ATDCs is crucial for identifying the causal relationship. Recipient countries include the first batch of 14 ATDCs for the pilot policy. In contrast, non-recipient countries include the rest of the African countries, allowing us to compare the grain production between recipient and non-recipient countries. The pilot policy consists of demonstration and non-demonstration food crops and five other crops with crop-level identification schemes. Finally, the implementation period was after 2006. The pilot countries began the technical cooperation phase between 2009 and 2012. They then moved into the sustainable development and commercial operation phase from 2012 until the end of the sample period. The non-implementation period was between 2000 and 2006, which allows us to compare the effects of the pilot policy before and after implementation and observe its long-term dynamic effects.

3. Research design

3.1. Data sources

This paper uses panel data of 15 food crops from 54 African countries during the 2000–2018 period. The output, trade data, and other economic data of food crops in African countries are all from FAOSTAT. The pilot countries were selected based on Li et al. (2017) and information provided on the official websites of ATDCs, the Ministry of Commerce, and the Ministry of Agriculture and Rural Affairs. Additionally, the Global Chinese Official Finance Dataset is extracted from Aid Data compiled by the Global Research Institute of the College of William & Mary to match the detailed data of China's agricultural aid projects in African nations. FAOSTAT reports food security, nutrition, and land use indicators, while the International Food Policy Research Institute (IFPRI) has issued a global hunger index (GHI). Additionally, the pan-African and non-partisan research network Afrobarometer has conducted surveys to gather data on

agriculture, rural areas, and farmers at the country level.

China's ATDCs are mainly implemented in two groups of demonstration countries. The first batch of ATDCs was determined at the Third Forum on China-Africa Cooperation in 2006. The number was increased to 14 during the implementation, including Benin, Cameroon, Congo-Brazzaville, Ethiopia, Liberia, Mozambique, Rwanda, South Africa, Sudan, Tanzania, Togo, Uganda, Zambia, and Zimbabwe. The second batch of ATDCs was determined at the Fourth Forum on China-Africa Cooperation in 2009. This paper selects the first batch of 14 ATDCs determined in 2006, for the first batch of ATDCs began to be built in February 2007, and all entered the technical cooperation stage before June 2011, with a long enough sample period for observation. Some projects were halted during the construction of the second batch of ATDCs due to local conflicts (Zhang and Qin, 2018). As of 2018, only one new ATDC had been built in the Democratic Republic of Congo (Geng et al., 2018). Thus, the second batch of ATDCs is not included in this study.[1]

The first batch of 14 ATDCs has selected demonstration crops such as rice, corn, wheat, soybean, cotton, banana, and various animal species, including beef cattle, broiler chicken, laying hens, catfish, and tilapia. This paper selects only rice, corn, wheat, paddy, and sorghum as research objects and matches them with corresponding FAOSTAT varieties. The stable supply of grain crops can effectively ensure food security in African countries compared with FAOSTAT food varieties. Regarding seed technology, China has developed a comprehensive breeding system for its main crops, such as rice and wheat, giving it a competitive edge in the global breeding industry. China has always aimed for self-sufficiency in grain and staple food security. Rice, corn, and wheat are the main grains in many countries. To explore the impact of ATDCs on local agricultural development, we focus on a single type of crop, given that crops have different farming conditions and technical requirements (Gao, 2016).

Finally, FAOSTAT supplies harvest area, grain production, unit yield, and output value, is from. Trade data include import and export volume and amount, with producer price data selected. Barley, buckwheat, canary seeds, fonio, corn, millet, oats, quinoa, rice, rye, sorghum, triticale, and wheat are all food crops. The country-level data, such as their capital, population, macro indicators, and investment, are obtained from FAOSTAT. The Forum on China-Africa Cooperation was created in 2000 as a collaborative platform for dialogue between China and African nations in South-South cooperation. The latest agricultural data available for African countries pertains to 2018; therefore, the sample period for analysis has been selected as 2000 to 2018.

3.2. Variable construction

The primary dependent variables are food crops of African countries, including production, trade, and price. The core dependent variables are harvest area, grain production, and unit yield, which are denoted by "$Area_{irt}$," "$Prod_{irt}$," and "$Yield_{irt}$," respectively. The second group of dependent variables is about trade, including import volume, value of imports, export volume, and value of exports, which are denoted by "$ImpQn_{irt}$," "$ImpVal_{irt}$," "$ExpQn_{irt}$," and "$ExpVal_{irt}$," respectively. The third group of dependent variables is about price, including producer price and output value, denoted by "PP_{irt}" and "GPV_{irt}" respectively. Dependent variables are all in the logarithmic form.

The core independent variables consist of three variables: recipient country, policy implementation year dummy, and demonstration food crops. The value of the variable of countries where the first batch of ATDCs is located at "$ATDC_r$" is 1; otherwise, it is 0. The value of the dummy variable "$Post_t$" equals one if after the implementation of the policy in 2006 and zero otherwise. Demonstration food crops include rice, corn, wheat, paddy, and sorghum. In the case of the five demonstration food crops, the value of "$Crop_i$" is one; otherwise, it is zero.

As other factors at the country level may also impact crop output and trade, this paper controls for country-level factors that affect capital, labor, investment, and macroeconomic indicators. Land is an essential means of production and input factor in agriculture. This paper selects the area of agricultural land denoted by $AgLand_{rt}$. Capital is another crucial input factor for increasing agricultural production and efficiency. $AgFixCap_{rt}$ denotes agricultural fixed capital. Labor, denoted by $RuralPop_{rt}$, is the main input factor of traditional agriculture. Investment affects agriculture's technical level and reproduction input, and the total foreign direct investment is set and marked by FDI_{rt}. The macroeconomic situation affects agricultural production. Hence, GDP is selected and denoted by GDP_{rt}. All the above variables are logarithmic, based on the 2015-dollar price. Table 1 shows the descriptive statistics of core dependent, policy, and control variables.[2]

3.3. Identification model

This paper adopts the triple DID model to identify the impact of ATDCs on the output and trade of food crops in Africa by comparing recipient countries and non-recipient countries, demonstration food crops and non-demonstration food crops, as well as before and after the implementation of the aid policy. The benchmark model is as follows:

$$Output_{irt} = \beta_0 + \beta_1 ATDC_r \times Post_t \times Crop_i + \rho X_{rt} + \alpha_i + \gamma_r + \delta_t + \lambda_{rt} + \mu_{it} + \upsilon_{ri} + \varepsilon_{irt}, \quad (1)$$

where, the core independent variable $Output_{irt}$ represents the harvest area, production and unit yield of food crop i in African country r in

[1] We thank one anonymous review for constructive comment. We could not obtain the launching time for each ATDC in host countries in Africa. Thus, we could not adopt the staggered DID method.

[2] The reason why the output data is less than the trade data is that many African countries do not produce food crops, but import and export a large number of food crops.

Table 1
Descriptive statistics.

Variable	Meaning	Observations	Mean	S.D.	Min	Max
Food crop output panel data						
Area	Harvest area	4986	10.612	2.948	0.000	16.638
Prod	Grain production	4986	10.495	2.870	0.000	16.105
Yield	Grain yield per unit	4924	9.328	0.790	0.693	12.450
PP	Producer price	5007	2.227	2.813	0.000	7.954
GPVconstant	Output value of grain (constant price)	5007	7.327	5.064	0.000	15.003
GPVcurrent	Output value of grain (current price)	5007	6.798	5.192	0.000	15.647
AgLand	Agricultural land area	4999	9.458	1.510	3.807	11.830
AgFixCap	Agricultural fixed capital consumption	5032	8.083	1.749	4.657	13.024
RuralPop	Rural population	4994	8.917	1.342	4.057	11.485
GDP	Gross Domestic Product	4841	4.761	1.649	0.263	9.287
FDI	Foreign Direct Investment	4798	5.700	1.963	−0.889	9.936
ADTC	Dummy variable of ATDCs	5434	0.287	0.452	0	1
crop	Dummy variable of demonstration crop	5434	0.629	0.483	0	1
Post	Dummy variable of policy implementation time	5434	0.632	0.482	0	1
Food crop trade panel data						
ImpQn	Grain import volume	7385	4.967	4.686	0.000	16.252
ImpVal	value of grain imports	11,742	2.734	3.892	0.000	15.121
ExpQn	Grain export volume	11,742	1.058	2.526	0.000	14.773
ExpVal	value of grain exports	11,742	0.864	2.131	0.000	13.609
AgLand	Agricultural land area	11,034	8.896	2.098	0.916	11.830
AgFixCap	Agricultural fixed capital consumption	11,106	8.128	1.686	4.657	13.103
RuralPop	Rural population	11,018	8.419	1.743	3.719	11.485
GDP	Gross Domestic Product	10,742	4.402	1.764	0.263	9.287
FDI	Foreign Direct Investment	10,570	5.608	1.899	−0.889	9.936
ADTC	Dummy variable of ATDCs	11,742	0.275	0.447	0	1
crop	Dummy variable of demonstration crop	11,742	0.439	0.496	0	1
Post	Dummy variable of policy implementation time	11,742	0.632	0.482	0	1

Source: FAOSTAT. Note: Except for dummy variables, all other variables are in the logarithmic form.

year t, which are denoted by $Area_{irt}$, $Prod_{irt}$ and $Yield_{irt}$ respectively. $ATDC_r$ represents the dummy variable of the pilot countries of ATDCs. The value of $ATDC_r$ for the countries where the first batch of ATDCs are located is 1; otherwise, it is 0. $Post_t$ is a dummy variable before and after the policy pilot. After the implementation of the policy in 2006, its value is one; otherwise, it is zero. $Crop_i$ denotes the dummy variable of demonstration crops. If it is a demonstration crop, the value is one; otherwise, it is zero. X_{rt} denotes control variables of other influencing factors at the country level, including agricultural land area ($AgLand_{rt}$), agricultural fixed capital consumption ($AgFixCap_{rt}$), rural population ($RuralPop_{rt}$), gross domestic product (GDP_{rt}) and foreign direct investment (FDI_{rt}).[3] In the empirical analysis of further discussions, based on Model (1), the dependent variable is replaced by food crop trade data to measure the impact of the pilot policy on food crop trade. The import volume ($ImpQn_{irt}$), value of imports ($ImpVal_{irt}$), export volume ($ExpQn_{irt}$), and value of exports ($ExpVal_{irt}$) of food crops are investigated, respectively. Based on the model (1), the dependent variable is replaced by the value data of food crops to measure the influence of the pilot policy on the value of food crops. The producer price (PP_{irt}) and grain output value (GPV_{irt}, including current price and constant price) of food crops are investigated, respectively. The above variables are all in the logarithmic form.

The benchmark model controls fixed effects, including α_i for country, γ_r for year, and δ_t for food crops. The formers α_i and γ_r absorb crop-level unobservable factors of individual heterogeneity that do not change with time. In addition, λ_{rt} is a country × year fixed effect, *and* μ_{it} is a crop × year fixed effect. υ_{ri} is a country × crop fixed effect, which helps filter out macroeconomic fluctuations across countries and years, price or demand fluctuations of other crops across years, and regional or demand fluctuations of different crops across countries. For example, the country × year fixed effect is used to control the impact of local conflicts, economic crises, and natural environment (disasters, temperature, precipitation, and soil fertility) on agricultural output in different countries in different years. The crop × year fixed effect is used to control the influence of fluctuations in factors such as international grain price, commodity cycle, and crop substitution on agricultural output for different crops in different years. The country × crop fixed effect helps control the impact of fluctuations in factors such as planting habits and land types on agricultural output for different crops in different countries. Finally, ε_{irt} is a random disturbance term.

In the benchmark model (1), coefficient β1 of $ATDC_r \times Post_t \times Crop_i$ is the parameter of interest. This coefficient captures the effectiveness of ATDCs in improving the production of demonstration food crops in the recipient countries by comparing outcome variables between the demonstration food crops and the non-demonstration food crops and between recipient countries and non-recipient countries during the pre- and post-implementation periods. If β_1 is statistically significantly positive, the pilot policy improves food security in recipient countries; if β_1 is negative, ATDCs are not conducive to food security in recipient countries.

[3] When the country-time fixed effect λ_{rt} is controlled, the country-level control variable X_{rt} will be absorbed by the fixed effect.

4. Empirical results

4.1. Parallel trend test

Figs. 1 and 2 show the parallel trends of food crop harvest area and yield, respectively. In the figures, the horizontal axis represents years, and the vertical axis represents the average annual output of crops in recipient countries and non-recipient countries. From 2000 to 2006, the sample period was considered as the non-pilot period. The pilot period was from 2007 to 2018. The year of policy implementation is shown by a vertical line in 2006. The solid black line represents the average annual output of demonstration food crops, while the gray dotted line shows the yearly production of non-demonstration food crops. The figures illustrate that the average annual output of demonstration and non-demonstration food crops remained unchanged in countries that did not receive the policy.

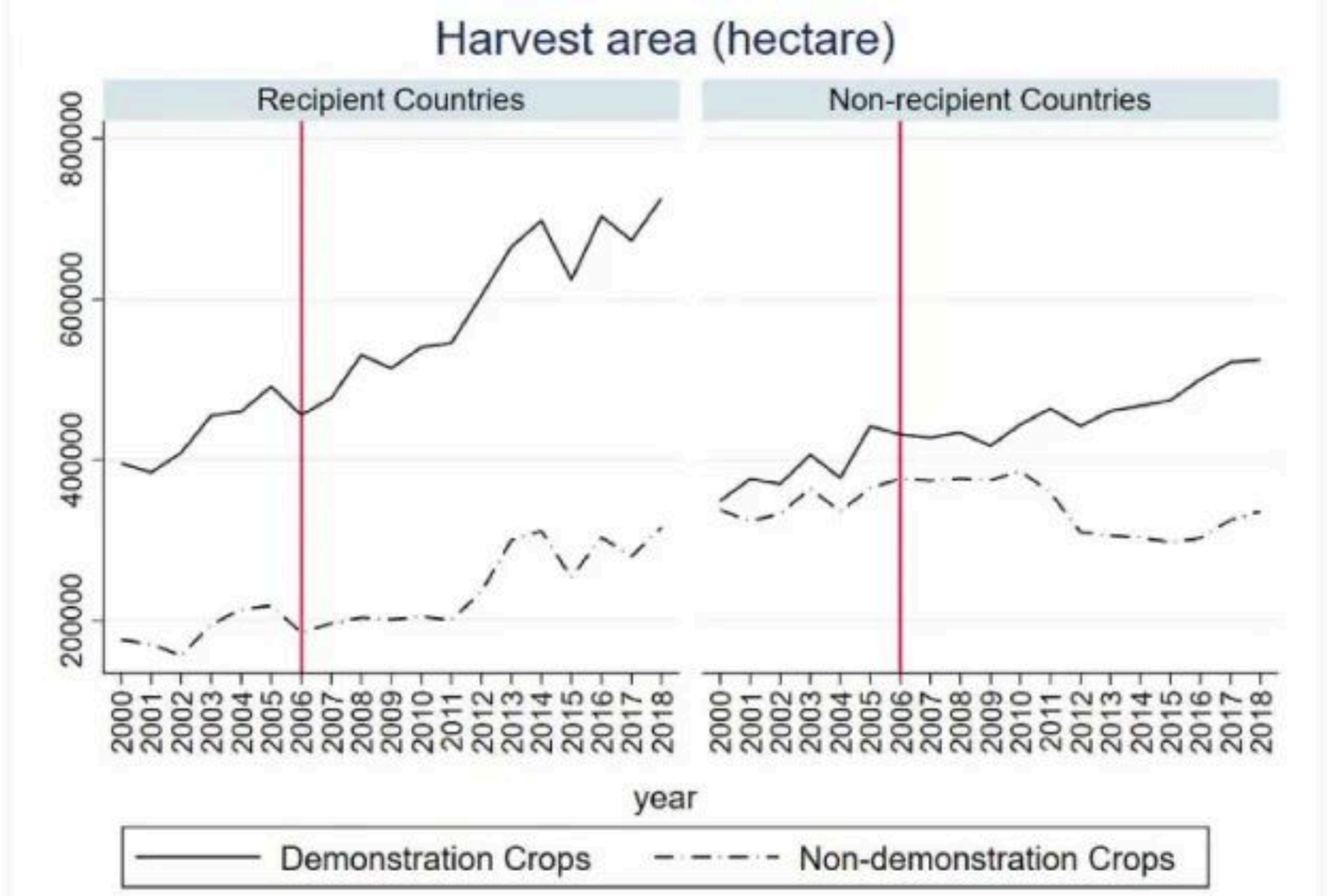

Fig. 1. Parallel trend of crop harvest area.

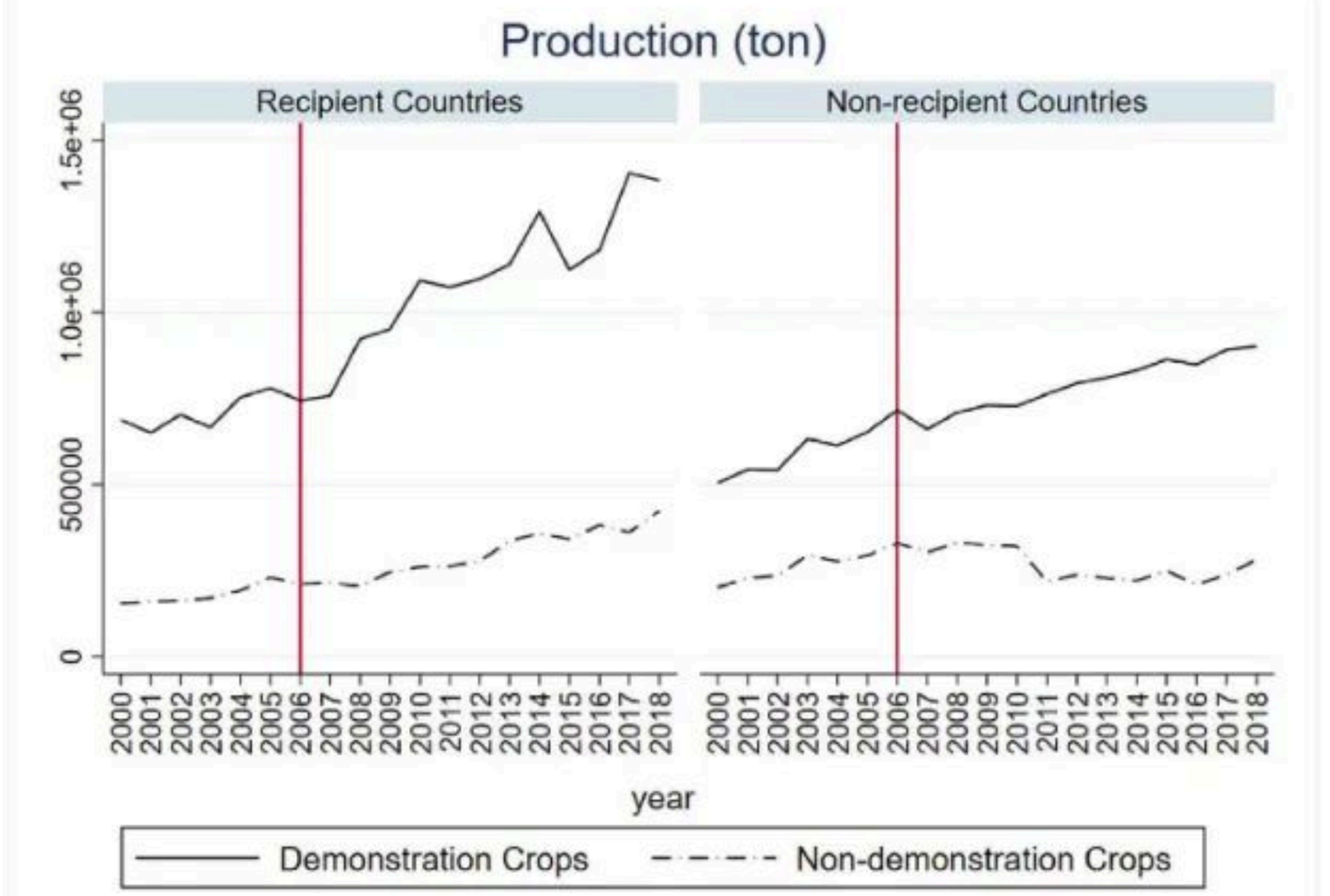

Fig. 2. Parallel trend of crop production.

Table 2
The influence of ATDCs on crop output.

Variable	*Area*		*Prod*		*Yield*	
	(1)	(2)	(3)	(4)	(5)	(6)
$ATDC_r \times Post_t \times Crop_i$	0.295**	0.216**	0.321**	0.159**	0.020	−0.060
	(0.118)	(0.094)	(0.116)	(0.070)	(0.066)	(0.054)
$ATDC_r \times Post_t$	−0.181*		−0.218*		−0.024	
	(0.095)		(0.102)		(0.048)	
$Crop_i \times Post_t$	−0.023		−0.095		−0.067*	
	(0.144)		(0.164)		(0.036)	
$ATDC_r \times Crop_i$	0.544		0.359		−0.188	
	(0.760)		(0.858)		(0.155)	
AgLand	0.509		0.211		−0.079	
	(0.431)		(0.362)		(0.313)	
AgFixCap	0.124***		0.168***		0.041*	
	(0.031)		(0.043)		(0.023)	
RuralPop	0.779*		0.872		0.113	
	(0.412)		(0.564)		(0.342)	
GDP	−0.001		−0.004		−0.003	
	(0.007)		(0.008)		(0.003)	
FDI	−0.011		−0.014		−0.005	
	(0.012)		(0.013)		(0.004)	
Observations	4573	4477	4573	4477	4513	4402
R^2	0.565	0.982	0.585	0.979	0.513	0.929
Crop fixed effect	Y		Y		Y	
Country fixed effect	Y		Y		Y	
Year fixed effect	Y		Y		Y	
Country × year fixed effect		Y		Y		Y
Crop × year fixed effect		Y		Y		Y
Country × crop fixed effect		Y		Y		Y

Note: All interaction terms and constant terms are controlled in the model. The standard errors clustered at the crop level are in brackets, and *, **, and *** indicate the significance levels of 10%, 5%, and 1%, respectively.

This means there was no significant difference in the yearly output trend before and after the policy was implemented in 2006.[4] After the policy was implemented in 2006, the output of demonstration food crops increased annually in recipient countries, while the production of non-demonstration food crops remained stable. Figures can support the parallel trend hypothesis in harvest areas or output.

4.2. Empirical results

This paper investigates the impact of ATDCs on agricultural output in Africa. Table 2 reports the baseline regression results from model (1). Columns (1) and (2) examine the harvest area, and columns (3) and (4) examine the output, while columns (5) and (6) focus on unit yield. Firstly, the model includes the fixed effect at country, crop, and year levels. It further adds the fixed effects of country × year, crop × year, and country × crop to test the robustness of the conclusion. Standard errors clustered at the level of the crop level are reported in the parenthesis.

First, columns (1) and (2) show the regression results of the harvest area of food crops. This paper focuses on the estimation coefficient of $ATDC_r \times Post_t \times Crop_i$. Column (1) controls the fixed effects of crop, country, and year and the economic variables at the country level. The estimation coefficients of $ATDC_r \times Post_t \times Crop_i$ are positive. They are significant at 5%, indicating that the ATDCs have a positive role in increasing the harvest area of food crops in Africa. After further controlling the country × year fixed effect, crop × year fixed effect, and country × crop fixed effect, Column (2) still reports a positive estimation coefficient, which is significant at 5%. The coefficient value decreases slightly, indicating that the additional fixed effects help explain the change in food crop harvest area and further prove that ATDCs have a positive role in increasing grain harvest area. Second, columns (3) and (4) report the food crop yield regression results. The estimation coefficients of $ATDC_r \times Post_t \times Crop_i$ are positive, all of which are significant at the level of 5%. Finally, columns (5) and (6) report the regression results of the unit yield of food crops, and the estimation coefficients are insignificant.

The above analyses show that the model's fixed effects and related control variables allow us to accurately observe the pilot policy's causal impact on the demonstration food crops in the recipient countries. Our preferred models are in columns (2) and (4). After controlling other factors in African countries, the pilot policy makes the harvest area and output of demonstration food crops in recipient countries increase by 24.11% and 17.23% on average compared with non-demonstration food crops; the pilot policy can improve the output of demonstration food crops in recipient countries. Still, it needs to increase the unit yield of demonstration food crops in recipient countries. The agricultural resource endowment information of the countries where the ATDCs are located shows that most of

[4] The authors find that non-demonstration crops of millet and barley in non-recipient countries showed a decrease in harvest area and output after 2010. After removing these two non-demonstration crops, this paper remakes figures of parallel trend, re-estimates the triple difference-in-differences model, and finds that the above conclusion is robust.

the recipient countries have the following characteristics before the implementation of the pilot policy: (1) there is sizeable arable land area, but the proportion of cultivated or cultivated area is limited; (2) it is mainly based on small-scale farming, with low technical level and mechanization; and (3) crops are weak in disaster resilience and infrastructure such as irrigation is slaggished. Therefore, at the initial stage of the implementation of the pilot policy, the improvement of the output of demonstration food crops in recipient countries takes precedence over the unit yield.

4.3. Robustness tests

To ensure the robustness of the conclusion of the benchmark model, this paper carries out robustness tests, including the dynamic effect and alternative model. First, this paper empirically tests the dynamic output effect of the pilot policy by using the event analysis method as follows:

$$Output_{irt} = \beta_0 + \sum_{n=1}^{6} \beta_n ATDC_r \times Post_{t-n} \times Crop_i + \sum_{m=1}^{12} \beta_m ATDC_r \times Post_{t+m} \times Crop_i + \rho X_{rt} + \alpha_i + \gamma_r + \delta_t + \lambda_{rt} + \mu_{it} + \nu_{ri} + \varepsilon_{irt} \quad (2)$$

where, 2006, when the pilot policy was implemented, is the base year. β_n represents the estimated value in each year before the policy implementation from 2000 to 2005, while β_m captures the estimated value in each year after the policy implementation from 2007 to 2018. The former reflects the parallel trend effect, while the latter indicates the long-term dynamic effect. The definitions of other variables are the same as those in Model (1).

Figs. 3 and 4 show the estimation results of β_n and β_m under a 95% confidence interval. Fig. 3 plots the dynamic effect with food crop harvest area $Area_{irt}$ as the independent variable, while Fig. 4 shows the dynamic effect of food crop production $Prod_{irt}$ as the independent variable. The estimation coefficient β_n of the parallel trend effect is not statistically significant from 2000 to 2006, indicating no significant differences between the treated and control groups before the pilot policy. Thus, the parallel trend hypothesis is further verified. In addition, the estimation coefficient β_m of the dynamic effect of the pilot policy was not different from zero in 2007 and 2008. In 2009, three years after the implementation of the policy, the estimation coefficient began to rise sharply, significantly at the level of 5% and gradually stabilized. The results of the dynamic effect estimation indicate that the pilot policy had a delayed impact on the output of demonstration food crops. In addition, the dynamic effects in Figs. 3 and 4 are consistent; that is, promoting effects of pilot policy became significant in 2009, further strengthening the conclusions.

Second, as a triple DID model is used in this paper to verify the robustness of the conclusion further, $ATDC_r \times Crop_i$ is combined into a variable $ATDC_{ri}$, and this variable and $Post_t$ are combined into a difference-in-differences estimation coefficient $ATDC_{ri} \times Post_t$. The result is robust, with little change compared with corresponding coefficients in Model (1), and the harvest area and output are significant at 5%.

5. Further discussion

This paper explores whether a pilot policy can lessen the reliance of recipient countries on grain trade and increase the value of their grain in the supply chain. We focus on the impact of ATDCs on agricultural trade in Africa and present the regression results in Table 3. Columns (1) and (2) analyze import trade, while columns (3) and (4) concentrate on export trade. After controlling for other factors in African countries, a pilot policy was implemented to show how certain food crops affect import volume and value. The results indicate that, on average, the import volume of these demonstration food crops decreased by 24.65% and the value by 4.69% compared to non-demonstration food crops. However, the results were found to be statistically insignificant. On the other hand, the pilot policy resulted in a significant 53.03% increase in the export volume and a 47.85% increase in the value of exports of demonstration food crops in

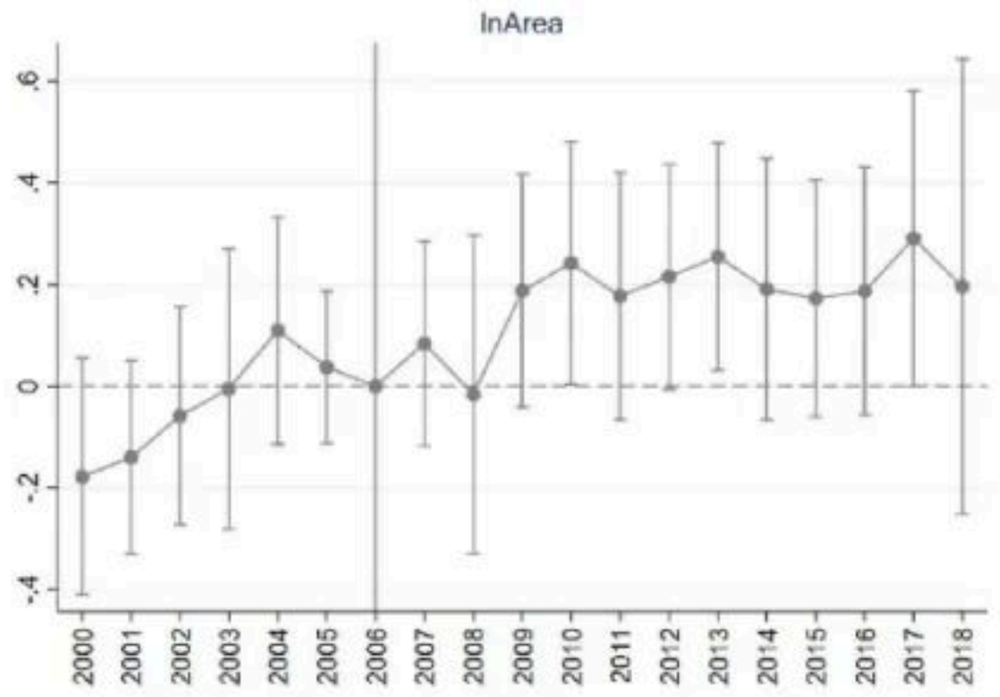

Fig. 3. Dynamic effect of crop harvest area (by year).

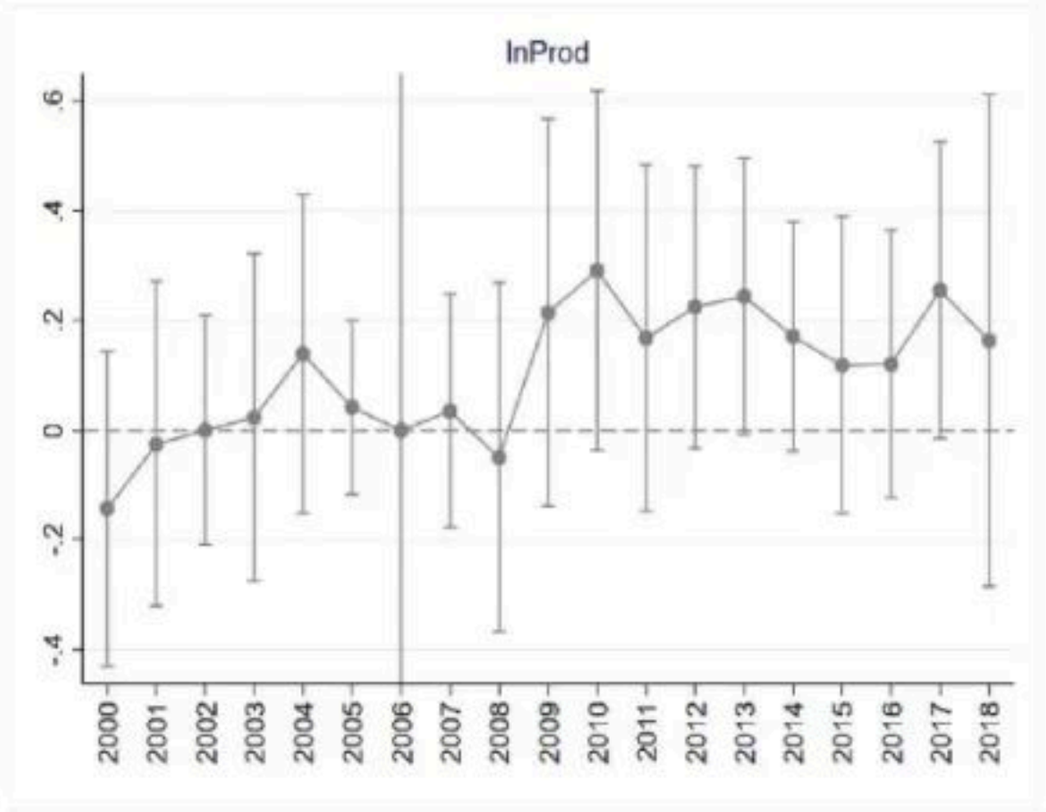

Fig. 4. Dynamic effect of crop output (by year).

Table 3
Impact of ATDCs on the crop trade.

Variable	*ImpQn*	*ImpVal*	*ExpQn*	*ExpVal*
	(1)	(2)	(3)	(4)
$ATDC_r \times Post_t \times Crop_i$	−0.283	−0.048	0.432*	0.391*
	(0.479)	(0.293)	(0.214)	(0.195)
Observations	6546	10,296	10,296	10,296
R^2	0.881	0.894	0.764	0.764
Control variable	Y	Y	Y	Y
Country × year fixed effect	Y	Y	Y	Y
Crop × year fixed effect	Y	Y	Y	Y
Country × crop fixed effect	Y	Y	Y	Y

Note: The model controls all the interaction terms, control variables, and constant terms. The standard errors clustered at the crop level are in brackets, and *, **, and *** indicate the significance levels of 10%, 5%, and 1%, respectively.

recipient countries compared to non-demonstration food crops. This highlights the potential of the pilot policy to reduce these countries' dependence on foreign trade for demonstrating food crops. In addition, we examine the dynamic effect and model replacement aspects to ensure the reliability of the benchmark model's findings on food crop trade, which are consistent.

Secondly, it is crucial to consider importing and exporting grain from the host countries and to analyze the number of countries involved in each process. This allows us to evaluate both the intensive and extensive margins. To do this, we replaced the dependent variables in the benchmark model with the number of importing and exporting countries. Our findings reveal that ATDCs are valuable in expanding the number of trading countries to demonstrate food crops in recipient nations. Notably, the positive impact on the number of countries exporting is statistically significant at the 10% level.

Finally, we investigate the impact of ATDCs on the value of agricultural food in Africa. The estimation coefficients show that the pilot policy positively affects the producer price and output value of demonstration food crops in recipient countries.

6. Mechanism

To investigate the mechanism of ATDCs, this section explores different aid methods and implementing agencies. Additionally, we assess the impact on agriculture, rural areas, and farmers.

6.1. Aid methods

The GCOF, or Global Chinese Official Finance Dataset, provides comprehensive data on international Chinese official finance projects from 2000 to 2014, according to reports by Dreher et al. (2019) and Li et al. (2021). Each aid project is evaluated from multiple angles, and this paper focuses on four quantifiable factors to conduct a scientific evaluation of the policy: (1) diversification of aid sources (triangulation); (2) number of additional aid resources (count); (3) field integrity (field); and (4) the number of funds invested in aid (USD). The data for each aid project includes information on capital flow, such as debt cancellation, debt replacement, export credit, foreign direct investment, free-standing technical assistance, grants, loans, joint ventures with recipients, scholarships/training from contributors, and strategic/supplier credit. Additionally, each aid project contains information about the Chinese implementing

agencies, including scientific research institutions, state-owned enterprises (SOEs), non-SOEs, and government agencies. We have collected all the data on aid projects in GCOF, including activities related to China's ATDCs in African countries. After combining the aid projects into panel data at the country-year level and matching it with the panel data of food crop output, we obtain the panel data of aid evaluation at the country-ATDC level.

6.2. Effects of aid types

To investigate the influence of aid fund types on the output of food crops in Africa, the core dependent variable $ATDC_r$ in Model (1) is replaced by the evaluation variable of aid fund types in the countries where the first batch of ATDCs are located. The variables for evaluating the fund types of aid projects related to the first batch of ATDCs in countries where ATDCs are located are "*ATDC_TA*" and "*ATDC_GR*," respectively. Under various evaluation indexes, the effects of two types of aid funds on the output of food crops are investigated. The model is constructed as follows:

$$Output_{irt} = \beta_0 + \beta_1 ATDC\_TA_{rt} \times Post_t \times Crop_i + \beta_2 ATDC\_GR_{rt} \times Post_t \times Crop_i + \rho X_{rt} + \alpha_i + \gamma_r + \delta_t + \lambda_{rt} + \mu_{it} + \nu_{ri} + \varepsilon_{irt} \quad (3)$$

where ATDC_TArt and ATDC_GRrt represent free-standing technical support funds and donor funds that change with time. The definitions of other variables are the same as those in Model (1).

Table 4 reports the regression results of the impact of aid fund types of ATDCs on African agricultural output. Columns (1) and (2), columns (3) and (4), columns (5) and (6), as well as columns (7) and (8) examine the effects of aid fund types on the harvest area and output of food crops from four aspects of the diversification of aid sources, the number of additional resources, the field integrity, and the number of investment funds, respectively. The pilot policy's free-standing technical assistance fund increased the harvest area and output of demonstration food crops in recipient countries by an average of 5.34% and 6.72%, respectively, compared to other aid fund types. Compared to other aid funds, the donor fund reduces the harvest area and output of demonstration food crops in recipient countries by an average of 2.66% and 4.69%, respectively. The seed industry in China has a well-established breeding system for important grain crops like rice and wheat. By providing technical assistance, it is possible to enhance the output of demonstration food crops in other countries.

To investigate the influence of implementing agencies on the output of food crops in Africa, the core dependent variable $ATDC_r$ is replaced by the evaluation variable $ATDC\_ia_r$ of aid implementing agencies in the countries where the first batch of ATDCs are located. The evaluation criteria used by aid implementing agencies for ATDCs in the countries where the first batch of ATDCs are located include aid projects implemented by Chinese research institutions, SOEs, and non-SOEs. SOEs increase the harvest area and output of demonstration food crops in recipient countries by an average of 5.97% and 5.65%, respectively, compared to other implementing agencies. On the other hand, the results of scientific research institutions and non-SOEs are insignificant. Regarding the implementing agencies of the ATDCs, China has selected several SOEs with high scientific and technological strength to cooperate with recipient countries.

6.3. Other effects

How do the Agricultural Technology Development Centers (ATDCs) benefit Africa? To evaluate food security, FAOSTAT calculates the logarithms of the change rate of per capita grain output, the proportion of permanent cropland used for agriculture, and the area of irrigated farmland. The Afrobarometer survey's second question, which asks how frequently food shortages are considered the most critical issue, is used to measure the level of hunger. The IFPRI's global hunger index serves as an indicator to assess food insecurity further. At the country level, we create outcome variables for agriculture, rural areas, and farmers. After implementing the pilot policy, recipient countries demonstrated significant improvements in agricultural indicators compared to non-recipient countries. Specifically,

Table 4
Influence of aid fund types of ATDCs on crop output.

Variable	Triangulation		Count		Field		USD	
	Area	*Prod*	*Area*	*Prod*	*Area*	*Prod*	*Area*	*Prod*
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
$ADTC\_TA_{rt} \times Post_t \times Crop_i$	0.052**	0.065**	0.044	0.057*	0.049	0.064	0.041**	0.052***
	(0.024)	(0.025)	(0.029)	(0.031)	(0.042)	(0.041)	(0.018)	(0.017)
$ADTC\_GR_{rt} \times Post_t \times Crop_i$	−0.027	−0.048**	−0.014	−0.032	−0.021	−0.041*	−0.014	−0.027*
	(0.023)	(0.022)	(0.022)	(0.021)	(0.022)	(0.024)	(0.014)	(0.016)
Observations	3315	3315	3315	3315	3315	3315	3385	3385
R^2	0.984	0.981	0.984	0.981	0.984	0.981	0.985	0.982
Control variable	Y	Y	Y	Y	Y	Y	Y	Y
Country × year fixed effect	Y	Y	Y	Y	Y	Y	Y	Y
Crop × year fixed effect	Y	Y	Y	Y	Y	Y	Y	Y
Country × crop fixed effect	Y	Y	Y	Y	Y	Y	Y	Y

Note: The model controls all the interaction terms, control variables, and constant terms. The standard errors clustered at the crop level are in brackets, and *, **, and *** indicate the significance levels of 10%, 5%, and 1%, respectively.

the change rate of per capita grain output increased by 228.05%, the proportion of permanent cropland used for agriculture increased by 199.52%, and the area of irrigated farmland rose by 591.71%. Additionally, the frequency of food shortages, the most critical issue in the second question, decreased by 2.37%, and the hunger index dropped by 61.83%. These results suggest that the pilot policy has positively impacted agriculture, rural areas, and farmers in recipient countries.

7. Conclusions and policy implications

This study analyzes the effects of Agricultural Technology Demonstration Centers (ATDCs) on the food security of recipient countries through a quasi-natural experiment utilizing FAOSTAT data with a triple DID approach. The results indicate that adopting agricultural technology and practices significantly enhances crop yield and harvest area, particularly in developing nations. The robustness tests confirm the parallel trend and dynamic effect, demonstrating that the policy also enhances the output of food crops in recipient countries. Additionally, the ATDCs increase the value of demonstration food crops in recipient countries, indicating the benefits of this policy. Further discussion reveals that ATDCs reduce dependence on demonstration food crops in recipient countries. The mechanism test reveals that free-standing technical support and state-owned ATDCs have a more significant positive impact. The ATDCs promote an increase in per capita grain output, the proportion of permanent cropland in agricultural land, and the expansion of irrigated land. They also aid in reducing the frequency of food shortages, which are considered crucial, and lower the hunger index.

Our research reveals significant policy implications. Through empirical analysis from an international political economy perspective, we uncover causal relationships in China's foreign aid. Our findings demonstrate that South-South cooperation has the potential to boost food crop production while reducing recipient countries' reliance on trade. These results highlight China's commitment to supporting other developing nations in realizing their full potential, promoting self-sufficiency, and fostering a global community through South-South cooperation.

Secondly, our research offers China an opportunity to expand its global partnerships and collaboration further, including initiatives like the Belt and Road Initiative and China-Africa cooperation. To enhance aid projects beyond agriculture, we suggest utilizing dedicated technical assistance to share relevant technologies, increase the provision of global public goods, and improve aid effectiveness. To support the implementation of China's ATDC policy, we recommend upgrading qualified ATDCs and consolidating superior demonstration crop varieties and planting areas. Moreover, providing agricultural technical assistance and cooperation that aligns with local conditions is crucial. Additionally, we propose establishing a joint laboratory for green agricultural technology between China and Africa to strengthen food security in Africa and beyond. This proposal is rooted in the 2021 Forum on China-Africa Cooperation in Senegal, the Belt and Road Initiative, and the African Union's Agenda 2063.

Finally, it is crucial to have reliable implementing agencies to ensure aid project mechanisms, which forms the basis for insisting on implementing agency diversification. To facilitate the ATDCs, we should leverage the benefits of South-South and tripartite cooperation in aid projects. We should also utilize the diverse advantages of scientific research institutions, state-owned enterprises, private enterprises, and government departments. It is essential to diversify aid sources, increase additional aid resources, and utilize the "10 + 10" mechanism of agricultural research institutions in China and Africa, ATDCs, agricultural experts from China, domestic and foreign training programs, and other resources. By strengthening joint research and development of agricultural technology and talent cultivation, we can achieve win-win and all-win results for aid projects.

Acknowledgments

Thanks to the support of the General Project of the National Natural Science Foundation of China (72073055), the Youth Scientific Research Initiation Project of the Chinese Academy of Social Sciences (2021YQNQD0056), and the INTERNATIONAL COOPERATION Project "Research on the Construction of the Belt and Road and China-Africa Infrastructure Cooperation" of Chinese Academy of Social Sciences.

References

Akhtaruzzaman, M., Berg, N., Lien, D., 2017. Confucius institutes and FDI flows from China to Africa. China Econ. Rev. 44, 241 252.
Chauvet, L., Ehrhart, H., 2018. Aid and growth: evidence from firm-level data. J. Dev. Econ. 135, 461 477.
Dolan, C.B., McDade, K.K., 2020. Pulling the purse strings: are there sectoral differences in political preferencing of Chinese aid to Africa? PLoS One 15 (4).
Dreher, A., Fuchs, A., Hodler, R., Parks, B., Raschky, P.A., Tierney, M.J., 2019. African leaders and the geography of China's foreign assistance. J. Dev. Econ. 140, 44 71.
Dreher, A., Fuchs, A., Parks, B., Strange, A., Tierney, M.J., 2021. Aid, China, and growth: evidence from a new global development finance Dataset. Am. Econ. J. Econ. Pol. 13 (2), 135 174.
Galiani, S., Knack, S., Xu, L.C., Zou, B., 2017. The effect of aid on growth: evidence from a quasi-experiment. J. Econ. Growth 22 (1), 1 33.
Gao, G., 2016. Function orientation and sustainable development suggestions for the China-Africa agricultural technology demonstration center. World Agric. (7), 200 204 (in Chinese).
Gehring, K., Kaplan, L., Wong, M.H.L., 2022. China and the world bank how contrasting development approaches affect the stability of african states. J. Dev. Econ. 158, 102902.
Geng, J., et al., 2018. Study on the formation mechanism and mode innovation of agricultural technology transfer in China and Africa. In: Li, A. (Ed.), Annual Review of African Studies in China (2017). Social Sciences Academic Press, Beijing, pp. 122 133 (in Chinese).
Guillon, M., Mathonnat, J., 2020. What can we learn on Chinese aid allocation motivations from available data? A sectorial analysis of Chinese aid to african countries. China Econ. Rev. 60, 101 265.
Guo, S., An, J., Jiang, H., 2022. Chinese Aid and Local Employment in Africa. Available at: SSRN 3718578.
Huang, Z., 2019. Local economic effects of Chinese aid projects: the case of Tanzania. World Econ. Politic. (8), 127 153 (in Chinese).
Humphrey, C., Michaelowa, K., 2019. China in Africa: competition for traditional development finance institutions? World Dev. 120, 15 28.