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Comparison of Rice Productivity Performances Between Different African Countries Using the Same Chinese Technology †

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Abstract: This paper explores the rice production changes spurred by the dissemination of Chinese rice technology across Egypt, Ghana, Kenya, Mali, Mozambique, and Tanzania (one group of the treated countries) through hybrid rice trials conducted from 1990 to 2010. The Difference-in-Differences model was applied for the above group. Another group, Burkina Faso, Burundi, Cote d'Ivoire, Rwanda, and Togo, was designated the control group, which did not receive treatment. Through hybrid rice trials, Sino–Africa cooperation has changed rice production levels. The Chinese rice dissemination technology performed well in terms of increasing rice yield (with an average of approximately 8.5 tons per hectare in the treated countries against 3.5 tons per hectare in the control countries) and ensuring rice-related self-sufficiency in Africa. The results of an empirical study show that, among the countries treated, Egypt remains the only African country to have established hybrid rice-breeding programs and released and produced domestically hybrid varieties. A redesign of the pattern of rice technology dissemination in Sino–Africa cooperation could, in the long term, improve rice production and productivity in the beneficiary countries.

Keywords: African rice productivity; game theory; Sino–Africa rice cooperation

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1. Introduction

Presently, the demand for rice is increasing in most African nations. Rice has become a cash crop and staple food due to rapid urbanization, the repatriation of refugees, and high demand from boarding schools, the army, and the police [1–3]. The People's Republic of China has introduced hybrid rice-breeding trials in some African countries to share essential technologies and skills for enhancing rice production. This paper attempts to respond to the following two questions: Did the Sino–Africa cooperation through Chinese hybrid rice trials compared between different African countries using the same Chinese technology lead to changes in rice outcomes? How has Chinese rice technology been disseminated in the beneficiary countries? This agricultural partnership has been a significant part of China–Africa cooperation, and Africa's hybrid rice-breeding trials have formed a bridge of Sino–Africa friendship [4,5].

2. Methods and Materials

Eleven African countries were selected: Benin, Burkina Faso, Burundi, Cote d'Ivoire, Egypt, Ghana, Kenya, Mali, Mozambique, Rwanda, Tanzania, and Togo. These countries constitute a significant region with a high potentially irrigable area (they own typical river basins—such as the Limpopo, Nile, and Volta—or share particular agro-ecological and hydrological areas), helping to boost local rice producers through Sino–Africa cooperation. The Difference-in-Differences approach (DiD) was used. The DiD model includes general treatment and control African countries. The treated (Tre) countries constitute the group of countries that received the treatment; control refers to the group of countries that were not treated.

Pre denotes the measurement before the program; Post denotes the measurement after treatment.

Chinese hybrid rice-breeding trials in Africa were considered an exogenous source of improving rice outcomes, which we refer to as the treatment. Rice yield was taken to be the outcome and dependent variable. Seven control variables proven to be interacting factors that boost the levels of rice productivity were selected: rice cultivation (V1), total dam capacity (V2), pesticide indicators (V3), percentage of land area shared for cropland (V4), irrigation water requirements (V5), percentage of irrigation equipment used for irrigation (V6), and agricultural researchers per 100 000 farmers (V7). The period analyzed was 1990 to 2010, and 1990 to 2010 and 2000 to 2010 are the pre- and post-treatment periods, respectively, with 0 and 1 representing the two dummy interacting variables. Egypt, Ghana, Kenya, Mali, Mozambique, and Tanzania served as 'a group of treated countries' ordered by treatment time ti*. The other group, consisting of Burkina Faso, Burundi, Cote d'Ivoire, Rwanda, and Togo, was designated the 'control group,' which did not receive treatment in terms of the data. The share of units in group t is ti, and the number of periods that group t spends under treatment is $\overline{Y}_t$.

This is equivalent to the following regression:

$$Y_{igt} = \gamma_g + \lambda_t + \beta \iota_{gt} + \varepsilon_{igt,}$$

where Y is the rice outcome, with 0 denoting the countries not treated, and 1 denoting the treated countries; ι is the dummy variable, which equals 1 for the countries treated in the treatment period; I denotes index individuals; g denotes index countries (1 = treatment country, and 0 = control country); t denotes index time periods (1 = post-treatment, and 0 = pre-treatment); $\gamma\gamma$ and $\lambda\lambda$ are group and period fixed effects; and $\epsilon\epsilon$ is a stochastic error term.

In this study, we developed seven indicators to examine rice outcome performance [6].

3. Results

The average rice yield in the treated and control countries, before and after the Chinese hybrid rice trials in Africa $\left(\overline{Y}_{Pre}, \overline{Y}_{Pos}\right)$, was determined, and the results in Figure 1/A show gaps in the trends across countries. The situation is similar before and after treatment in both the treated and control countries. Egypt exhibits a high average rice yield.

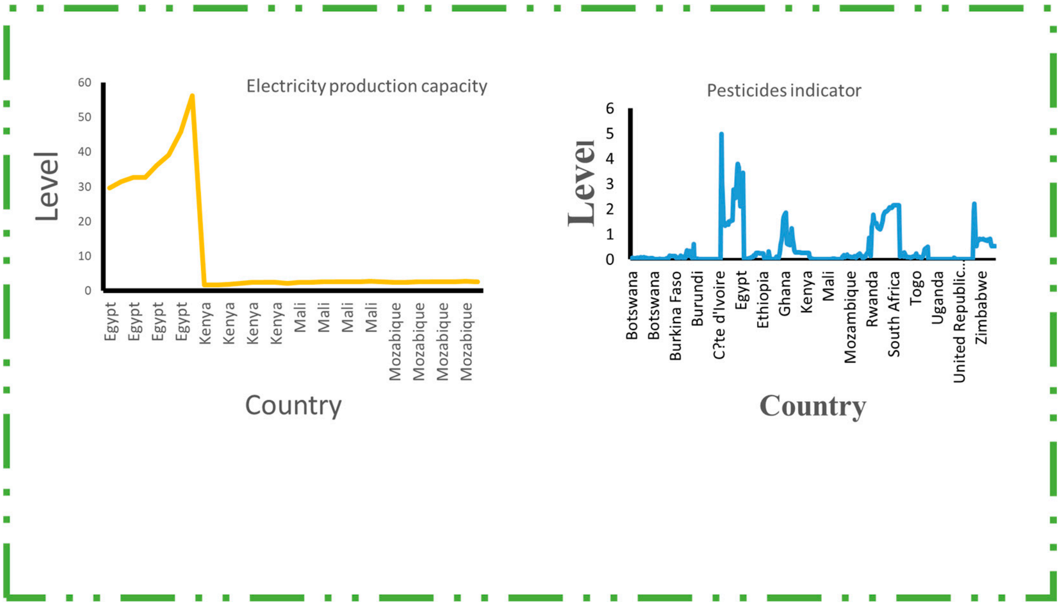

Figure 1. Overview of some indicators involved in increasing the cost linked to the implementation of irrigation infrastructures and rice productivity. Source: authors (software output).

When we compare the costs of rice production and various determinants of rice production, it becomes clear that Egypt has an absolute advantage over the other African countries in terms of optimizing rice production. Nonetheless, Egypt is a desert country. Egypt also remains better off regarding the determining factors increasing cost and the use of area for rice cultivation. It is also gainful in regard to rice production and various rice inputs linked to increasing rice productivity in Africa.

The results in Table 1 show that that there was an increase of 1% in pesticide indicators, the percentage of area set aside for rice farmers, efficient irrigation water reuse, and rice farmers for extension and research services, implying growth equal to 1.1617, 0.8447, 0.1315, and 0.6239 in rice productivity, with the following significance levels (p-values): (p) < 0.1, 0.05, 0.05, and 0.01, respectively.

Table 1. Difference-in-Difference estimation.

y	Coefficient	P > $\|t\|$
DiD	−0.499 ***	0.001
lv1	−0.312 **	0.016
lv2	−13.837 ***	0.000
lv3	1.161 *	0.073
lv4	0.844 **	0.024
lv5	0.131 **	0.028
lv6	−0.068	0.7247
lv7	0.6239 ***	0.002
_cons	39.944 ***	0.000

* $p < 0.1$, ** $p < 0.05$, and *** $p < 0.01$. Source: authors (software output).

Some economists and scholars agree on some factors that can influence rice production and productivity (Figures 1 and 2). They attribute the increased yield from rice hybrids to the size of the area cultivated, the availability of nutrients in organic fertilizers, the irrigation infrastructures, the efficiency of water use, the existence of public and agricultural infrastructures, and research and development. The increase in the area dedicated for rice farms mainly depends on the size of the irrigated area. In Africa, there is a correlation between the unit cost for the location of irrigation infrastructures to be implemented and the quality of existing infrastructures [7–9].

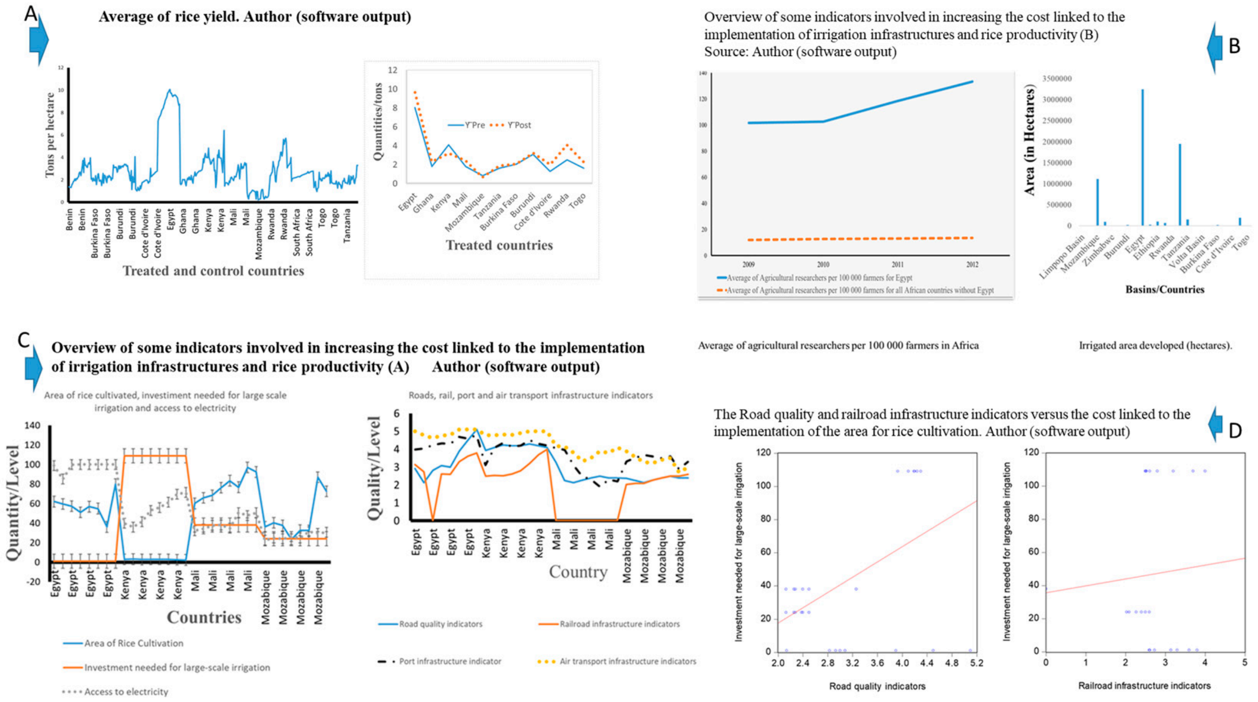

Figure 2. Overview of some indicators involved in improving rice productivity.

4. Conclusions and Discussion

The Sino–Africa ties regarding rice fields have provided advantages to African nations despite related challenges [10]. The Sino–Africa rice field partnership keeps communication channels open for all stakeholders [11] and allows mechanism management in formulating proposals and strategies to be achieved [12]. The adoption and development of hybrid rice technology in Africa are still hindered by the limited availability of local seeds (with seeds being supplied from external sources), limited knowledge of the high cost of imported seeds, vulnerability to pests and maladies, and limited human skills and capacity [7]. In Africa, rice farmers cope with barriers, mainly the absence of large irrigation schemas, water management inefficacy, a lack of water access, and poor distribution [13]. The low yields of rice are due to the small sizes of the areas devoted to rice cultivation, the rice varieties used, the inefficient quantity of fertilizer applied, and the absence of irrigation infrastructures and technologies [14]. The rice production decline in Africa can also largely be explained by the lack of public investment in infrastructure, farm research and extension projects, irrigation, electricity, and roads and inefficient use of water and farming inputs [15,16]. The degree of mechanization is also very low, resulting in a high rate of human labor used. Tillage machinery, planting machinery, and harvesting machinery are crucial tools for facilitating the mechanization of rice production, constituting one of the key rice productivity factors [17]. In spite of all the factors mentioned above that make it difficult to disseminate rice technologies among farmers in the host countries, the Chinese rice technology transfer has positively affected Africa's rice production. Thus, promoting hybrid rice technology in Africa is a pathway for increasing yields and incentivizing Chinese agricultural firms to invest more in rice research and development in this developing region [7–9].

We may question what allowed Egypt to exhibit a high yield (with 9.4 tons per hectare in Figure 1) compared with the other African countries. Among the treated countries, it is the only commercially developed nation to which this hybrid rice program of establishing and producing domestic rice seeds was applied. In Egypt, hybrid rice technology proved to be a promising pathway if Africa could become involved in (1) adopting adaptive varieties (with hybrid robustness) that can resist diseases and drought, (2) encouraging the private sector to ensure there is a permanent local supply by implementing an industrial system of rice seed production, and (3) research and development (R&D). African countries failed to perform well in developing the hybrid rice technology sustainably due to some determining factors, such as the lack of (1) local, appropriately trained human resources; (2) satisfaction with the procedures for hybrid rice cultivation necessitating local farmers' skills; (3) developed irrigation and transportation infrastructures; (4) nutrient access; and (5) advanced R&D [7–9].

To achieve sustainable rice productivity, Africa needs to select technological irrigation based on a combination of technologies founded on local abilities, adaptive seeds supplied locally, and established mechanisms that guarantee the capability of farmers to lead the whole value chain, including with respect to growing crops, harvesting, processing, and gaining access to a market with reasonable prices [18].

To make African countries better local rice producers, the Sino–Africa policy of rice cooperation needs to consider models for selecting the right seeds, selective technologies appropriate to African approaches, and the sharing of China's expertise on sustainable rice production. There is also a need to carefully diagnose how cooperation between China and Africa can be achieved and identify who the main actors must be [19]. African rice farmers must be integrated into all rice extension services. African and Chinese policymakers have to plan the strategic objectives to be achieved; they have to select the activities to prioritize, such as encouraging public and private investments in basic agricultural infrastructure and intervening in any possible land reform. This study suggests that Chinese donors are working to improve transportation and energy infrastructures in Africa, essential factors for decreasing the unit cost of irrigation infrastructures. Africa can achieve sustainable rice production once investors prioritize a stakeholder-participatory approach to dealing with rice farmers and regional potentialities [20].

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Abbreviations

The following abbreviations are used in this manuscript:

DiD	Difference-in-Differences
R&D	Research and development

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