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Dynamics of Agricultural R&D in BRICS: Investments, Innovation Pathways, and Productivity Outcomes

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Lakshmi Swathi Ganti, and
Tanya Singh

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Pratap Singh Birthal, Sachin Kumar Sharma, Lakshmi Swathi Ganti, and Tanya Singh*

Abstract: This paper investigates the dynamics of public investment in agricultural R&D and scientific manpower, assesses their productivity outcomes across the BRICS countries, and explores opportunities for collaboration. There are significant inter-country disparities in R&D capacity, with China leading in both investment and manpower, followed by India. Notably, China's research expenditure exceeds that of the US, and India is steadily narrowing the gap with the US. However, R&D spending as a proportion of agricultural GDP in China and India remains less than that in Brazil, South Africa, and developed countries. In other BRICS countries, this ratio is comparatively lower. Nevertheless, R&D capacity has expanded in most BRICS countries, albeit at variable rates. The productivity outcomes of R&D differ significantly across the BRICS countries. In general, total factor productivity (TFP) has increased, although the patterns are diverse across countries. However, TFP growth has decelerated in both Brazil and South Africa. It remained relatively robust in China, India, and Russia. Furthermore, there are significant differences in research priorities across countries, guided by relative factor endowments. In land-scarce, smallholder-dominated countries such as China and India, TFP is more strongly associated with R&D spending per hectare, indicating a greater emphasis on land-augmenting technological change. In contrast, in land-abundant, labor-scarce countries, such as Brazil and Russia, productivity gains are more closely associated with R&D spending per agricultural worker, reflecting priorities for labor-saving and scale-oriented technological changes. These findings suggest that this heterogeneity in R&D capacity and innovation pathways across the BRICS countries can be transformed into shared gains through effective collaboration, aligning with the BRICS Action Plan 2025-2028.

Keywords: Agriculture, research investment, innovation, productivity, BRICS cooperation

1. Introduction

The BRICS bloc, initially comprising Brazil, Russia, India, China, and South Africa, expanded in 2024-2025 to include Saudi Arabia, Egypt,

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the United Arab Emirates (UAE), Ethiopia, Iran, and Indonesia. The expanded BRICS covers roughly one-third of the world's land and freshwater resources, supporting nearly half of the global population. Furthermore, this group accounts for approximately 40 percent of the global GDP. Thus, the BRICS bloc has the potential to significantly influence not only the development trajectories of member countries but also global economic dynamics and the geopolitical order.

BRICS holds a significant position in global agriculture and food security. Its extensive geographical spread and diverse climatic conditions, ranging from tropical to temperate, provide a strategic advantage in producing a wide range of foods of both plant and animal origins. The expanded BRICS has a significant share in the global food production — over 60 percent of rice, 48 percent of wheat, 40 percent of maize, 50 percent of soybeans, 45 percent of pulses, 37 percent of milk, and 45 percent of meat. It also plays an important role in the global food trade, accounting for more than one-fifth of both exports and imports. Exports are dominated by cereals (30 percent), meats (20 percent), fruits (18 percent), sugar and honey (15 percent), and vegetables (12 percent), while imports comprise mainly dairy products (35 percent), cereals (21 percent), and fruits (20 percent). Notably, the trade patterns vary across the BRICS countries. The original BRICS bloc remains a net exporter of most agricultural commodities, whereas several of its new members have sizable trade deficits in a number of them.

Despite the significant contribution of the BRICS countries to global agricultural production and trade, nearly half of the world's undernourished population lives in these countries, with some facing severe food insecurity and high undernourishment rates (FAO, 2025). In Ethiopia, for example, over 61 percent of the population is vulnerable to moderate to severe food insecurity. Similarly, in Egypt, South Africa, and Iran, a large proportion of their populations, ranging from 21 percent to 38 percent, face moderate to severe food insecurity risks. Simultaneously, food production systems in the BRICS countries have been facing several structural, biotic, and abiotic challenges, including the dominance of small landholdings, degradation of natural resources, loss of biodiversity, and increasing intensity of climate change. According to Ortiz-Bobea (2021), over the last five decades, climate change has reduced the world's agricultural productivity growth by more than 21 percent, with countries located in the arid and semi-arid tropics experiencing larger reductions.

Science, technology, and innovation offer pathways to address the common challenges faced by the BRICS countries in their pursuit of achieving the shared goals of improving food security and nutrition, enhancing farmers' welfare, and reducing poverty. Breeding crops and animals for higher yields, nutritional quality, and resistance to biotic (pests and diseases) and abiotic stresses (droughts, floods, and heatwaves) can significantly enhance agricultural productivity while alleviating the pressure on scarce natural resources. Additionally, research on precision agriculture and climate-smart farming techniques, which utilize remote sensing, big data analytics, and the Internet of Things (IoT), can optimize resource use and improve the health of natural resources. However, it is important to acknowledge that agricultural research demands significant initial investments and involves long gestation periods with uncertain outcomes, all of which deter private-sector investment in agricultural R&D. Consequently, agricultural R&D in developing countries remains a public-funded activity.

Our findings reveal notable disparities in R&D capacities, innovation pathways, and productivity outcomes across the BRICS countries, influenced by differences in fiscal capacities, factor endowments, and agro-climatic conditions. Recognizing this, the BRICS Action Plan 2025-2028 emphasizes collaborations among BRICS members to advance agricultural sciences to address common challenges to agri-food systems. This study aligns with its four interlinked pillars of cooperation: (i) sustainable development and food security, (ii) science, technology, and innovation (STI), (iii) economic and development finance, and (iv) people-to-people and institutional cooperation.

The following section examines the key socioeconomic and demographic characteristics of the BRICS countries that influence their potential for food production, which are directly linked to the sustainable development and food security pillar of the BRICS Action Plan. Section 3 analyzes agricultural R&D capacity in terms of the scale and intensity of investment and scientific manpower, aligning with its science, technology, and innovation (STI) pillar. Section 4 examines the productivity outcomes of R&D investment, providing evidence of the efficiency and effectiveness of investment aligning with the STI and economic and development finance pillars. The final section outlines the pathways for cooperation in agricultural R&D among the BRICS countries, focusing on institutional capacity building, knowledge transfer, and sharing of best practices.

2. Structural Diversity, Factor Endowments, and Food Security

The BRICS countries share similarities and differences in certain agro-climatic, socioeconomic, and demographic traits, which underscore their individual strengths and weaknesses. This paves the way for collaboration across various agricultural domains, including agricultural research, which is vital for tackling the emerging challenges facing food systems. By harnessing their complementary strengths, cooperation in agricultural research, innovation, and policy can accelerate agricultural development in the BRICS countries.

Table 1 presents the key characteristics of the BRICS countries that may influence the trajectories of food system transformation. There are significant differences in income levels within BRICS. The inflation-adjusted per capita income in PPP $ (at the 2017 level) is much higher in the UAE and Saudi Arabia and is comparable to that of the US, Australia, and Germany. Ethiopia and India lie at the bottom of the income pyramid. The income levels in the rest of the BRICS countries, excluding Russia, range between 10,000 PPP$ to 20,000 PPP $.

Table 1: Key economic, demographic and agricultural characteristics of BRICS countries, 2020-2022

	GDP per capita (PPP $ at 2017 prices)	Population density (persons/sq.km.)	Prevalence of undernutrition (%of total population)	Prevalence of moderate to severe food insecurity (% of total population)	Rural population (%)	Cropland (million hectares)	Cropland (%of total land)	Cropland/ agricultural worker (ha)	Agricultural GDP (%of total GDP)	Agricultural workforce (%of total workforce)	Agricultural GDP/ hectares (PPP $ at 2017 prices) prices)/ hectare of crop land	Agricultural GDP/ hectares (PPP $ at 2017 prices) prices)/ agricultural worker
	BRICS											
Brazil	14629	25	<2.5	13.2	12.7	63.4	6.7	7.4	6.7	9.2	3229	24055
China	17849	150	<2.5	n.a.	37.5	127.7	11.6	0.7	7.7	23.3	15432	11377
India	6719	476	12.0	n.a.	64.6	168.0	51.9	0.8	17.5	43.8	9904	7553
Russia	27351	9	<2.5	2.8	25.1	123.4	7.4	29.5	3.9	5.9	1269	37443
South Africa	12769	51	10.0	20.7	32.2	12.4	9.9	14.8	2.7	20.6	1682	24844
	BRICS +											
Egypt	12303	111	9.4	30.8	57.1	4.0	3.2	0.8	11.3	19.5	38402	29239
Ethiopia	2333	108	19.7	61.4	77.8	15.8	14.5	0.4	37.0	63.6	6672	2977
Indonesia	11645	147	6.3	4.5	42.7	45.1	9.4	1.2	13.1	29.3	9372	10907
Iran	14856	55	6.8	38.8	23.7	17.6	9.7	4.4	12.2	15.6	9138	40592
Saudi Arabia	53585	15	<2.5	n.a.	15.5	3.6	1.6	8.2	2.7	2.9	12425	102062
UAE	65769	136	<2.5	3.6	12.7	0.1	0.7	0.9	0.9	1.5	64487	60901
	Developed countries											
Australia	53953	3	<2.5	13.8	13.6	31.4	4.0	89.7	2.5	2.5	1095	98205
Canada	47531	4	<2.5	10.2	18.3	38.4	4.3	145.0	1.9	1.4	893	129527
Germany	52913	238	<2.5	4.1	22.5	11.9	33.4	23.8	0.8	1.2	2959	70546
Japan	40880	345	n.a.	5.8	8.1	4.3	11.2	2.1	1.0	3.1	11751	24866
South Korea	44005	530	<2.5	5.4	18.6	1.5	13.7	1.0	1.8	5.4	25853	27084
United Kingdom	44477	277	<2.5	6.9	15.8	6.0	24.8	21.2	0.7	1.0	3559	75512
United States	62148	36	<2.5	10.3	17.1	155.9	16.7	66.4	0.9	1.7	1255	83282

Note: Except for nutrition-related indicators, which were taken from FAO, IFAD, UNICEF, WFP, and WHO (2025), all indicators were compiled from the World Bank's World Development Indicators.

The BRICS countries differ significantly in their resource endowments, especially in terms of land and labor, the key inputs in agricultural production. India has 168 million hectares of cropland, whereas the UAE has approximately one million hectares. India is the most populated country, followed by China. In India, approximately 65 percent of the population lives in rural areas and is primarily engaged in agriculture. China has 128 million hectares of cropland, and 38 percent of its total population lives in rural areas. Egypt and Ethiopia have large rural populations but less land available for agricultural use. Russia has nearly as much cropland as China but a significantly lower population, with only nine people per square kilometer.

This differential factor endowment across the BRICS countries results in significant differences in agrarian structures. Ethiopia, China, India, Egypt, and the UAE are land-scarce, with less than one hectare of land per agricultural worker. In contrast, Russia has nearly 30 hectares of arable land per worker, followed by South Africa (15 hectares), Saudi Arabia (8 hectares), and Brazil (7 hectares).These disparities are also reflected in farm size. In much of Asia, the average farm size rarely exceeds two hectares (Lowder et al., 2016), whereas it is approximately 82 hectares in Brazil (Parre et al., 2024), 150 hectares in Russia (gfas - global forum for rural advisory services: g-fras.org), and 264 hectares in South Africa (DRDLR, 2018). Small farms, those under 2 hectares, account for approximately 20 percent of all farms in Brazil, Russia, and South Africa. In contrast, in the other BRICS countries, the proportion of small farms exceeds 80 percent.

Accordingly, the modes of agricultural production vary across BRICS countries. Agriculture in Brazil, Russia, and South Africa is highly commercialized and capital-intensive, whereas in much of Asia, it is dominated by labor-intensive family farms, where productivity improvements depend on enhanced input-use efficiency, small-scale mechanization, and improved crop varieties. As a result, there are significant differences in land and labor productivity across the BRICS countries. Russia, South Africa, and Brazil have lower land productivity at 1,269, 1,682, and 3,229 PPP $ per hectare of cropland, respectively.

China and India have comparatively higher land productivity. Interestingly, despite its limited cropland, the UAE has significantly higher land productivity, followed by Egypt. Notably, land productivity is considerably low in non-BRICS, land-abundant developed countries.

Just as land productivity varies significantly, so does labor productivity. Labor productivity is relatively low in Ethiopia (2,977 PPP $/worker), followed by India (7,553 PPP $/worker). This is because, in both these countries, the agricultural sector engages a significantly larger proportion of the workforce. In contrast, Saudi Arabia and the UAE have higher worker productivity due to the dominance of capital-intensive, high-value agricultural production systems, engaging only a small proportion of the population. Comparative levels are significantly higher in developed countries, including Canada, Australia, the US, the UK, and Germany.

These differences highlight the relative importance of agriculture in the economic development of the BRICS countries. In Ethiopia, the agricultural sector employs approximately two-thirds of the total workforce and contributes about 36 percent to the GDP. In India, the sector engages approximately 44 percent of the workforce and contributes about 17 percent to the GDP. Likewise, in Indonesia, the sector remains critical to the livelihood of a significant proportion of the population, engaging approximately 30 percent of the workforce and contributing approximately 13 percent to the GDP.

On the other hand, the agricultural sector in Russia employs roughly 6 percent of the workforce and contributes less than 4 percent to GDP. South Africa has a different pattern, where the agricultural sector contributes less than 3 percent to GDP, but engages approximately one-fifth of the workforce, indicating structural dualism and labor market rigidities. On the other hand, in developed countries both within and outside the BRICS, the agricultural sector typically accounts for less than 3 percent of GDP and employment.

In general, crops comprise the dominant component of the agricultural sector in BRICS countries, accounting for approximately half of the total agricultural value added. The share of livestock in value-added varies significantly, generally falling between 30 and 50 percent. The contributions of fisheries and forestry also show significant inter-country differences. Fisheries contribute more in China, Egypt, the UAE, and Saudi Arabia, whereas forestry has a larger contribution in land-abundant Brazil, Russia, and South Africa.

Moreover, food and nutrition security indicators vary widely across the BRICS countries. Ethiopia appears to be the most food insecure, with 61 percent of its population experiencing moderate to severe food insecurity, followed by Iran and Egypt (FAO, 2025). India has an undernourishment rate of approximately 12 percent. Despite being economically more prosperous, South Africa and Brazil experience moderate to severe food insecurity risks, affecting approximately 20 percent and 13 percent of their populations, respectively. These indicators underscore the need to transform agri-food systems to improve the availability, affordability, and access to nutritious food in BRICS countries.

These differences in agri-food systems across the BRICS countries reflect their distinct research priorities and innovation pathways, which can serve as a foundation for effective collaboration in agricultural R&D. By leveraging their complementary strengths, such as Brazil's expertise in large-scale commercial production, the smallholder-focused innovations of India and China, Russia's technological and mechanization capabilities, South Africa's experience in maintaining rich biodiversity, and the fiscal strength of the UAE and Saudi Arabia, the BRICS countries can strengthen their R&D capacity through coordinated research agendas, technology co-development and transfer, capacity building, and knowledge sharing to address common challenges and achieve shared goals.

3. Agricultural R&D: Scale and Intensity

When incentives for private-sector investment in agricultural research are limited by long gestation periods and uncertain outcomes, public funding becomes essential for technological progress to address the challenges of agriculture and food production. In the BRICS countries, despite significant differences in their levels of economic development, most agricultural R&D funding comes from government budgets (Beintema et al., 2019; Sithole et al., 2019; Deng et al., 2021; Jayne et al., 2023; Ruane and Ramasamy, 2023; Kandpal et al., 2024). The share of private-sector investment in agricultural R&D in developing countries remains relatively low, typically less than 10 percent (Pardey et al., 2016). This reflects the public good nature of agricultural research, which demands significant public funding.

This study uses data from a newly created database, *the Global Research on Agriculture: Personnel and Expenditures (GRAPE)*. The GRAPE contains data on public expenditure and scientific manpower for 190 countries from 1960 to 2022. It draws data primarily from the Agricultural Science and Technology Indicators (ASTI), the Organisation for Economic Co-operation and Development (OECD), and national statistical sources. In this database, the investment series is harmonized, ensuring consistency with the ASTI and OECD definitions, and is expressed in PPP terms at constant 2017 prices. The database is publicly accessible via the Zenodo repository. *Van Dijk et al.* (2025) provide detailed documentation of the data sources and harmonization procedures.

Despite its extensive scope, GRAPE has some limitations. First, the reported data may differ because of variations in how subnational government expenditures are treated and covered in different countries. Second, inconsistencies in reporting and the unavailability of data can impact comparability across countries. Finally, data gaps and the need for interpolation might have introduced bias. Therefore, the findings presented in this study should be viewed as indicative of general trends rather than precise estimates.

3.1. S*cale of R&D investment and scientific manpower*

Table 2 shows the trends in R&D investment and scientific manpower. The scale of investment and trends therein differ significantly across the BRICS countries, influenced by their financial capabilities and the size of their agricultural sectors. China leads in investment, spending an average of 7,800 million PPP $ (at 2017 prices) in 2020-2022, which is more than twelve times the amount spent in the mid-1990s. During this period, India's R&D investment increased by more than fourfold, from 1,060 million PPP $ to 4,364 million PPP $. Russia also witnessed a significant increase, from 308 million PPP $ to 859 million PPP $. Conversely, Brazil saw a sluggish improvement in it, from 1,988 million PPP $ in the mid-1990s to 2,496 million PPP $ by 2009-2011, and then a slight decline. In South Africa, investment remained nearly stagnant between 1994-1996 and 2009-2011, and subsequently decreased by nearly 30 percent to reach 232 million PPP $ by 2020-2022.

Among the new BRICS members, Egypt and Ethiopia have consistently increased their spending on agricultural R&D. The trends in R&D investment in other BRICS countries are uneven. Interestingly, the combined R&D investment of the new BRICS countries is approximately equivalent to that of Brazil, about half of that of India, and roughly one-third of that of China.

The scientific manpower, measured as the number of full-time equivalent (FTE) researchers[1],also varies considerably among the BRICS countries. China has over 45,000 FTE researchers, almost four times that of India. Russia and Brazil each have more than 6,500 FTE researchers. South Africa has a much smaller number of FTE researchers, only 760. The trend in FTE researchers varies significantly from country to country. The scientific manpower expanded in China, India, and Brazil, decreased in Russia, and remained largely unchanged in South Africa. In other BRICS countries, manpower has expanded considerably. In Iran, the number of FTE researchers increased by more than fivefold, from 2,235 in the mid-1990s to over 12,000 in 2020-2022, approaching those of India. In Egypt, their number nearly doubled, exceeding 10,000. Ethiopia has also witnessed a rapid increase. Interestingly, the total manpower engaged in agricultural R&D in the new members of BRICS, which was nearly equivalent to that of India in the mid-1990s, is now three times larger.

Table 2: Levels and trends in R&D investment and scientific manpower in BRICS countries

	Expenditure (million PPP $ at 2017 prices)			Manpower (FTE number)		
	1994-1996	2009-2011	2020-2022	1994-1996	2009-2011	2020-2022
	BRICS					
Brazil	1988	2496	2385	5183	5498	6559
China	623	3822	7800	34096	33579	45271
India	1060	2575	4364	12190	10504	12326
Russia	308	660	859	6084	7222	6528
South Africa	330	340	232	917	760	760
	BRICS+					
Egypt	242	364	524	5574	6850	10163
Ethiopia	51	115	224	491	1691	3602
Indonesia	478	816	636	3466	4164	4555
Iran	541	301	499	2235	6417	12621
Saudi Arabia	186	143	198	389	305	414
UAE	7	6	9	26	25	36
	Developed countries					
Australia	636	656	733	7295	8894	10609
Canada	855	881	917	2456	2376	2800
Germany	1110	1358	1679	5322	5120	6520
Japan	2771	3024	2588	22754	16231	15909
South Korea	501	1015	1429	2495	6423	8356
United Kingdom	823	675	592	4019	3423	3556
United States	4635	5927	5036	10478	9063	8360

Source: GRAPE database

Furthermore, in most BRICS countries, the expansion of scientific manpower is not commensurate with the increase in R&D investment. In Brazil, China, India, Russia, and South Africa, the expansion of manpower broadly matches the increase in R&D investments. However, in the rest of the BRICS countries, the number of researchers rapidly increased, significantly outweighing the increase in R&D investments. This imbalance leads to differences in R&D spending per researcher, which can affect the efficiency, productivity, and quality of agricultural research.

How do the agricultural R&D capacities of the BRICS countries compare with those of the developed countries? Table 2 also presents the level of investment and manpower deployed in agricultural research in selected developed countries, including Australia, Canada, Germany, Japan, South Korea, the US, and the UK. Compared to developed countries, most BRICS countries have experienced a rapid increase in agricultural R&D capacity in terms of both investment and manpower. For example, China's investment in R&D is now more than 1.5 times that of the US, having increased from less than one-fifth in the mid-1990s. Similarly, India is rapidly closing this gap. On the other hand, the US, UK, and Japan have experienced a decrease in R&D investment as well as in scientific manpower. Furthermore, it is interesting to note that R&D spending per researcher remains significantly higher in developed countries, which has significant implications for the efficiency and quality of research outputs.

These findings unequivocally demonstrate a profound transformation in the landscape of global agricultural research, with emerging market and developing economies, such as China and India, consolidating their research capabilities to address domestic agricultural challenges and harness emerging opportunities.

3.2. R*esearch intensity*

To compare R&D capacity across countries, it is important to assess not only the absolute level of R&D spending but also its intensity relative to the size of the agricultural sector. The most widely used indicator of intensity is the ratio of R&D spending to agricultural GDP (AgGDP). However, this ratio has its limitations. This ratio can vary significantly in contexts where AgGDP fluctuates. A decrease in AgGDP may artificially inflate this ratio, while a rapid increase could lower it, even if research spending is on the rise. Hence, this measure should be complemented with indicators such as R&D spending per hectare or per agricultural worker.

These alternative measures of research intensity provide insights into the nature of technological change. The Induced Innovation Theory (Hayami and Ruttan, 1971) suggests that the nature of technological change in agriculture is guided by the relative scarcity of key production factors, such as land and labor. R&D spending per hectare of cropland, a quasi-fixed production input, reflects efforts to enhance land productivity, improve input-use efficiency, and promote sustainability, thereby resulting in land-augmenting technological change. Meanwhile, R&D spending per agricultural worker captures the stock of knowledge capital available per worker and reflects labor-augmenting technological change.

Table 3 presents the different indicators of research intensity. R&D investment as a proportion of AgGDP has remained consistently low in the BRICS countries, except in Brazil and South Africa, where it has historically remained higher at over one percent. However, in the past few years, this ratio has decreased significantly in both countries. In South Africa, it dropped from 2.2 percent to 1.1 percent, while in Brazil, it decreased from 1.8 percent to 1.2 percent. Currently, in Russia, this ratio stands at approximately 0.55 percent, up from 0.25 percent in the mid-1990s.

In China, the ratio of R&D investment to AgGDP increased exponentially from 0.11 percent in the mid-1990s to 0.40 percent in 2020–2022. In contrast, India maintained a comparatively lower ratio of 0.20–0.29 percent. Interestingly, in the mid-1990s, India's research intensity was nearly twice that of China. For the other BRICS countries, agricultural R&D investment relative to AgGDP varies widely, from 0.15 percent in Indonesia to 0.34 percent in Egypt. Nevertheless, there has been a significant decline in this ratio in Iran and Indonesia.

In contrast, developed countries typically spend 2-5 percent of their AgGDP on agricultural R&D. However, this percentage decreased in some countries. For example, in the US, it decreased from 3.53 percent during 2009-2011 to 2.77 percent in 2020-2022.

Table 3: Levels and trends of research intensity in BRICS countries

	R&D expenditure as % of AgGDP			R&D expenditure per ha of cropland (PPP dollar at 2017 prices)			R&D expenditure per agricultural worker (PPP dollar at 2017 prices)		
	1994-1996	2009-2011	2020-2022	1994-1996	2009-2011	2020-2022	1994-1996	2009-2011	2020-2022
	BRICS								
Brazil	1.75	2.04	1.16	39.1	40.5	37.6	182.4	248.2	280.1
China	0.11	0.31	0.40	4.8	28.5	61.1	1.7	13.7	45.0
India	0.20	0.29	0.26	6.2	15.2	26.0	5.5	11.9	19.8
Russia	0.25	0.55	0.55	2.4	5.3	7.0	31.5	119.3	205.2
South Africa	2.21	2.23	1.11	23.8	26.5	18.7	336.9	503.4	276.5
	BRICS+								
Egypt	0.33	0.30	0.34	76.8	99.3	130.3	45.6	53.4	99.2
Ethiopia	0.26	0.24	0.21	5.7	7.8	14.2	2.9	4.0	6.3
Indonesia	0.25	0.29	0.15	15.4	20.8	14.1	13.4	19.4	16.4
Iran	0.79	0.47	0.31	29.1	17.6	28.4	159.2	77.8	126.1
Saudi Arabia	0.44	0.47	0.44	49.1	38.3	54.5	447.9	214.5	447.7
UAE	0.18	0.18	0.16	82.4	72.5	104.3	59.8	33.6	98.5
	Developed countries								
Australia	3.15	2.77	2.13	35.0	23.0	23.3	1621.0	1930.5	2090.3
Canada	3.08	3.60	2.67	20.7	23.3	23.9	2013.5	2854.4	3458.3
Germany	3.42	4.39	4.79	92.1	112.4	141.6	993.9	2133.4	3376.2
Japan	3.66	5.76	5.06	550.0	659.1	595.0	758.5	1258.0	1259.1
South Korea	1.16	2.74	3.57	252.2	591.3	923.6	208.3	637.5	967.6
United Kingdom	3.61	3.96	2.76	136.3	111.1	98.0	1571.8	1963.9	2080.2
United States	3.11	3.53	2.57	25.3	36.0	32.3	1669.2	2708.9	2143.9

Source: Estimated from the GRAPE database and the World Bank's World Development Indicators database.

R&D spending relative to factor endowments, measured per unit of cropland and per agricultural worker, varies across the BRICS countries. On a per-hectare basis, Egypt records the highest expenditure, at approximately 130 PPP $, closely followed by the UAE. China and Saudi Arabia spend approximately 61 and 55 PPP $ per hectare, respectively. The middle tier includes Brazil, India, and Iran, with per-hectare expenditure ranging between 26 and 38 PPP$. Lower levels are observed in Indonesia, Ethiopia, South Africa and Russia.

A different pattern emerges when research intensity is measured on a per-agricultural worker basis. Saudi Arabia has the highest research spending at approximately 447 PPP $ per worker, followed by Russia, Brazil, and South Africa, each spending more than 200 PPP $. Iran, Egypt, and the UAE also have relatively high spending per worker compared to other BRICS countries, including China and India. Nevertheless, compared to developed countries, R&D spending per worker in the BRICS countries remains lower due to the significantly higher dependence of the workforce on agriculture.

4. R&D Investment and Total Factor Productivity

4.1 Total factor productivity (TFP) growth

Table 4 illustrates the annual growth in TFP, which reflects output gains resulting from technological advancements, efficiency improvements, and improved resource allocation rather than simply an increase in input usage. In essence, TFP growth is defined as the difference between output growth and input growth. From the mid-1990s to 2009-2011, Brazil experienced a robust TFP growth of over 3 percent, closely followed by China (2.7 percent) and South Africa (2.1 percent). India and Russia recorded modest TFP growth of 1.5 and 1.2 percent, respectively. However, during 2012-2022, TFP growth decelerated significantly in Brazil (0.6 percent) and South Africa (0.1 percent), and moderately in China (2 percent). India and Russia experienced a slight acceleration in TFP growth. The slowdown in TFP growth in Brazil and South Africa can be attributed to sluggish improvements in R&D capabilities, both in terms of funding and the scientific workforce, and possibly the onset of diminishing returns from previous technological advancements.

Table 4: TFP growth in agriculture in BRICS countries (percent per annum)

	1994-2011		2012-2022	
Countries	**Output growth**	**TFP Index growth**	**Output growth**	**TFP Index growth**
BRICS				
Brazil	4.45	3.11	2.10	0.57
China	4.08	2.70	1.83	1.96
India	2.89	1.48	3.49	1.82
Russia	0.63	1.24	3.16	1.57
South Africa	2.34	2.09	1.89	0.09
BRICS(+)				
Egypt	3.95	1.24	1.38	1.61
Ethiopia	5.62	2.56	3.07	-1.80
Indonesia	3.74	1.63	2.65	1.46
Iran	2.45	0.91	-1.38	-2.53
Saudi Arabia	2.31	0.64	7.59	7.47
UAE	1.85	-2.29	5.28	6.33
Developed countries				
Australia	0.78	0.17	0.30	-0.42
Canada	1.61	2.29	1.61	0.83
Germany	0.61	0.96	-0.63	1.09
Japan	-0.73	1.28	0.10	1.23
South Korea	0.37	1.53	0.44	1.08
United Kingdom	-0.32	-0.56	0.79	0.71
United States	1.22	1.03	0.96	-0.06

Estimated data available at: USDA, Economic Research Service.

TFP growth is more heterogeneous in other BRICS countries. In Ethiopia, TFP growth decelerated, turning negative from 2.6 percent during 1994-2011. Likewise, Iran experienced a significant deceleration in TFP growth, which turned negative during 2012-2022. On the other hand, Saudi Arabia and the UAE experienced a dramatic acceleration in TFP growth to 7.5 percent and 6.3 percent, respectively. Egypt and Indonesia maintained steady and positive TFP growth.

In contrast to the BRICS countries, TFP growth in most developed countries remains sluggish and displays varying trends. In Germany, Japan, and South Korea, TFP growth has remained relatively stable. Meanwhile, in Australia and the US, it has decelerated and turned negative in recent years. The UK experienced a reversal in TFP growth from negative to positive.

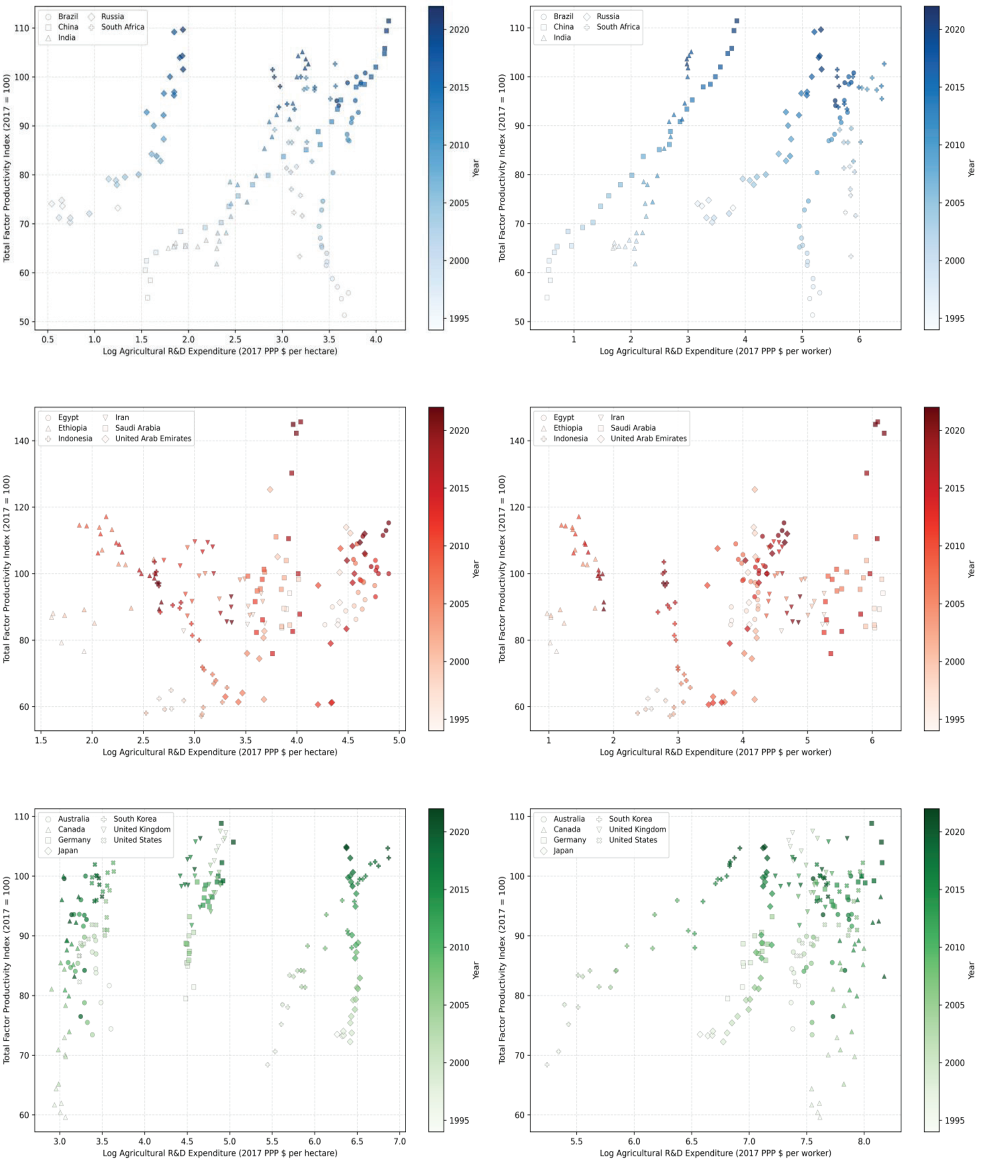
4.2 Research investment and TFP growth

Figure 1 depicts the correlation between the trends in the TFP index and agricultural R&D expenditure per hectare and per worker (in logs). Overall, the association between per-hectare spending on R&D and the TFP index is positive in most BRICS countries, although its strength and temporal dynamics vary significantly across countries. China, Brazil, and Russia show simultaneous increases in the TFP index and R&D intensity. India shows a similar but more gradual pattern of improvement. In contrast, South Africa follows a more uneven path, with fluctuations in TFP despite increasing R&D spending.

Likewise, a positive association is observed between the TFP index and agricultural R&D spending per worker. There is a strong co-movement between the two in the case of China and India, suggesting research investment effectively translating into technological progress and thereby an increase in labor productivity. Brazil and South Africa also show steady productivity improvements with rising R&D spending per worker. In contrast, Russia experiences comparatively modest and somewhat volatile TFP growth relative to its investment level.

For the remaining BRICS countries, TFP growth is generally positively associated with agricultural R&D intensity, although the magnitude and stability of productivity gains vary significantly. Egypt and Saudi Arabia show a positive relationship between per-hectare R&D spending

Figure 1: Relationship between R&D intensity with total factor productivity



and the TFP index, whereas Ethiopia's relatively low research investment is associated with lower productivity. Indonesia and the UAE suggest that moderate to high investment does not necessarily translate into stable productivity gains, whereas Iran displays mixed and volatile outcomes.

In developed countries, the association between agricultural R&D spending per hectare or per worker and TFP growth is positive and stable. Countries with higher R&D intensity, particularly the US, Japan, and South Korea, experienced higher TFP levels. Australia and Canada have relatively lower R&D intensity with more variable outcomes, although long-run trends remain upward. Over time, most countries move rightward and upward, indicating that sustained research investment supports steady and incremental productivity gains.

4.3 Innovation pathways

The observed relationship between research intensity and factor endowments has significant implications for technological change. The stronger association between R&D spending per hectare and TFP growth suggests that research focuses more on increasing output per unit of land, reflecting land-augmenting innovations. A stronger association between R&D spending per agricultural worker and TFP indicates that research focuses on labor-augmenting, capital-deepening innovations to increase operational efficiency and scale economies.

In countries with limited land, such as China, India, Egypt, the UAE, Japan, and South Korea, research focuses on augmenting land productivity. Agricultural research in these countries typically focuses on the development of crop varieties that enhance yield and tolerate stress, improve input-use efficiency, resource management techniques, protected cultivation, and climate-resilient agronomic practices. Given the constraints on expanding agricultural land, productivity growth largely relies on the extent of intensification and efficiency improvements.

In labor-scarce countries such as Brazil, Russia, the US, Australia, Canada, and Saudi Arabia, technological change is labor-saving and capital-deepening. These countries emphasize research on mechanization, automation, robotics, and digital agriculture to substitute scarce labor with capital and knowledge for enhancing economies of scale and operational efficiency.

The high benefit–cost ratios documented in the literature provide credence to the observed correlation between research intensity and TFP growth. Meta-analyses and global assessments suggest that investments in agricultural research yield higher returns compared to other public investments. For the Global South, the estimated benefit–cost ratio is as high as 33:1 (Rosegrant et al., 2023; Pardey et al., 2016). Similarly, an evaluation of research conducted in the institutions under the CGIAR[2] system revealed an average benefit–cost ratio of approximately 10:1 (Alston et al., 2020). Evidence at the country level further supports these findings. For Brazil, Akerman et al. (2025) estimated a benefit-cost ratio of approximately 17:1, whereas Kandpal et al. (2024) reported a ratio of approximately 14:1 for India.

5. Pathways for Cooperation in Agricultural R&D

This study demonstrates the crucial role of agricultural research in enhancing agricultural productivity and food supply in the BRICS countries. This provides some important policy insights for strengthening agricultural R&D capacity in the BRICS countries, as well as for fostering collaboration among them.

First, the significant differences in investment and scientific manpower among the BRICS countries highlight the necessity of customized policy strategies to improve R&D capabilities. Countries with less developed R&D infrastructure should increase public funding, expand their pool of scientific personnel, and improve their extension services. Meanwhile, countries such as China and India, which have relatively more advanced R&D systems, can further enhance their capacity to sustain technological gains realized from past investments.

Second, the significant variation in TFP growth among the BRICS countries underscores the need to enhance the effectiveness of R&D investment. This can be achieved by strengthening research-extension-farmer linkages and addressing structural, institutional, and policy barriers to the widespread adoption of technologies and innovations. In land-abundant countries, such as Brazil and South Africa, where TFP growth has decelerated, it is imperative to restore investment in R&D, expand scientific manpower, and reorient the agricultural research agenda to align with emerging challenges.

Third, heterogeneity in factor endowments underscores the importance of tailoring research to country-specific conditions. In economies characterized by limited land availability and a predominance of smallholder farmers, such as China and India, it is advisable to prioritize innovations that augment land productivity. Conversely, in countries with abundant land and relatively scarce labor, such as Brazil and Russia, the focus should be on adopting labor-saving and scale-enhancing technologies, including mechanization and digitalization of agriculture and agricultural value chains.

Fourth, the composition of the agricultural sector has important implications for research. The dominance of crops in low-income countries, such as Ethiopia, suggests the continued importance of investing in crop improvement, input-use efficiency, and climate-resilient farming systems to achieve self-sufficiency in staple foods. Simultaneously, the growing economic importance of livestock across countries suggests the need to invest more in animal science research, focusing on breeding, health, nutrition, management, and processing. Likewise, the growing role of fisheries in countries like China, Egypt, the UAE, and Saudi Arabia suggests a greater focus of research on intensification of aquaculture and mariculture. Similarly, Brazil, Russia, and South Africa should emphasize research on sustainable land use and forest management.

Based on these insights, Table 5 presents a blueprint for strengthening collaboration in agricultural R&D among the BRICS countries. This framework broadly aligns with the BRICS Action Plan 2025-2028 and follows a sequential process that reinforces the co-financing of joint research programs to co-develop technology, knowledge, and innovation, which will subsequently be transferred to farming communities and other stakeholders through supportive institutions and policies.

Table 5: Strategic focus and priority actions for cooperation in agricultural R&D

	BRICS Action Plan 2025-2028	Strategic focus	Priority actions
Financing	Economic Cooperation & Development Finance	Mobilizing resources for agricultural R&D	• Long-term commitment to funding. • Co-finance shared research infrastructure and regional centers of excellence • Explore additional avenues for finance
Technology	Science, Technology, and Innovation (STI) Cooperation	Joint development and diffusion of technologies	• Develop a common research agenda Promote cross-border technology transfer • Collaboration in genomics, precision agriculture, and resource-efficient technologies
Institutions	People-to-People, Knowledge, and Policy Cooperation	Strengthening research systems, human capital, and policy learning	• Establish innovation hubs, incubators, and pilot platforms • Develop researcher and student exchange programs • Collaborative policy research and regular policy dialogues
Outcomes	Sustainable Development, Food Security & Climate Action	Delivering inclusive, resilient, and nutrition-sensitive transformation	• Enhance land and labor productivity • Improved nutritional values • Strengthen climate adaptation and resilience strategies

Source: Author's compilation.

5.1 Sustained funding is necessary for strengthening collaboration in agricultural R&D

Agricultural research requires considerable upfront investment, involves long gestation periods, and may not always produce the envisaged outputs. This suggests the need for reliable public funding for agricultural research for long-term partnerships. The significant disparities in financial and innovative capacities among the BRICS countries indicate that rich countries may contribute more finances, while those with a comparative advantage in scientific expertise can contribute their skills and technical knowledge to forge strong collaboration in agricultural R&D.

In addition to government funding, BRICS should explore other avenues for financing collaborations in agricultural research. These include co-financing agreements with multilateral development banks and blended finance with contributions from private agribusinesses and philanthropic sources. Public–private partnerships offer significant potential for private investment in research and technology commercialization. Furthermore, financing instruments such as climate finance can support research on sustainability, climate resilience, and food system transformation.

5.2 Develop common research agenda for co-development of technologies and innovations

Guided by their factor endowments, the BRICS countries vary in their food systems and, thus, in their research priorities. In land-scarce countries, the research agenda should be anchored to maximizing land productivity while conserving natural resources, with a greater research focus on developing crop varieties that are both high-yielding and resilient to climate change, soil and water conservation techniques, and precision agriculture. Labor-scarce countries prioritize research on mechanization, automation, and digital innovation to address labor constraints.

Given this diversity in the landscape of agriculture and research priorities among the BRICS countries, a mutually agreed-upon research agenda is essential to address the common challenges of sustainable food system transformation. The agenda should be based on the comparative strengths of each country. For example, China and India's expertise in smallholder innovations can provide scalable models for improving the productivity and resilience of smallholder agriculture. Brazil's leadership in climate-smart tropical agricultural systems offers valuable insights into adapting agriculture to changing environmental conditions. South Africa's experience in agri-biodiversity management can contribute to conserving genetic resources and promoting ecosystem services. The Brazilian Agricultural Research Corporation (Embrapa) and the Indian Council of Agricultural Research (ICAR) collaborate under the Brazil–India Cross-Incubation Programme in Agritech. This initiative aims to facilitate the exchange of best practices and foster innovation in sustainable agriculture, digital technologies, and value chain development, thereby supporting resilient and inclusive food systems.

Cooperation in frontier areas such as genomics, precision agriculture, digital technologies, and resource-efficient climate-smart solutions offers significant potential to accelerate sustainable agricultural intensification. Advances in genomics can support the development of high-yield and climate-resilient crop varieties. Precision agriculture and digital technologies, such as remote sensing and artificial intelligence can lead to data-driven farm management decisions. Strengthening joint research and knowledge exchange in climate-smart agriculture can improve adaptive capacities. Through shared expertise and resources, the BRICS countries can accelerate the diffusion of innovation and promote resilient, efficient, and sustainable food systems.

5.3 Institutions and policies are essential to translate research into impact

Strong institutions translate agricultural R&D investments into tangible outcomes. In this context, joint innovation hubs, incubators, and pilot platforms play significant roles. Such platforms can serve as interfaces between research institutions, extension systems, and farming communities. Collaborations in digital innovations, digital extension systems, and data-sharing platforms can strengthen research-extension-farmer linkages.

Improving the quality of human resources through targeted exchange programs, joint doctoral and post-doctoral training, and thematic research networks can facilitate cross-border learning, promote the exchange of best practices, and improve the overall quality of scientific personnel. These initiatives can contribute to long-term research partnerships.

Furthermore, collaboration in sharing best policy practices can facilitate the development of evidence-based and context-specific policy frameworks. This may include the co-design of institutional innovations, regulatory reforms, and incentive structures tailored to the diverse national conditions.

5.4 Potential outcomes

The primary objective of cooperation in agricultural R&D among the BRICS countries is to leverage their complementarities to address the common challenges that the food systems face. By pooling financial and scientific resources, such partnerships can accelerate the generation of new technologies and innovations.

Given the increasing frequency and intensity of extreme climate events, enhancing resilience of agriculture should be central to collaborative research efforts. Collaborative research can focus on developing crop varieties that withstand climate challenges, enhance water and fertilizer use efficiencies, and promote conservation agriculture. Moreover, investing in climate information systems, early warning systems, and digital advisory services will enhance the adaptive capacity of the BRICS countries.

Moreover, given the high levels of malnutrition in some BRICS countries, it is crucial to ensure that their populations have access to affordable, healthy diets. Engaging in collaborative research on biofortification and integrated farming systems, along with the exchange of the best nutritional practices, will significantly contribute to the development of inclusive, nutrition-sensitive food systems across the BRICS countries.

To implement this framework, the BRICS Agricultural Research Platform (BARP) must be effectively operationalized through long-term funding commitments for a clearly defined, common research agenda. This necessitates not only financial support from member countries but also the evolution of pooled funding mechanisms for co-financing joint research programs. Developing a shared and forward-looking research agenda, focusing on areas such as climate resilience, sustainable intensification, digital agriculture, and nutrition-sensitive innovations, will be critical for aligning national priorities with the collective goals. Platforms for regular dialogue, knowledge exchange, and sharing best practices further strengthen collaboration and accelerate technology diffusion across countries.

Strengthening coordination across national research systems in BRICS is crucial to foster synergies in priority areas, reduce duplication of efforts, and improve research efficiency. This necessitates the establishment of governance frameworks with clearly defined roles and responsibilities, as well as mechanisms for monitoring and evaluating collaborative research.

Endnotes

[1] FTE is a standard metric for assessing researchers' workloads, particularly when they engage in various activities such as teaching and administrative duties. It effectively translates part-time work into the equivalent number of full-time work.

[2] CGIAR stands for the Consultative Group on International Agriculture and is a network of specialized research centers dedicated to key areas such as crop improvement, natural resource management, livestock and fisheries systems, biodiversity conservation, and food policy

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