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POLICY BRIEF

Water, Policy, and Agriculture Productivity in Egypt

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When water scarcity restricts agricultural production, expanding water resources is only one option to increase or maintain output; investments in research to raise land and water productivity can also release constraints on growth. This *Policy Brief* draws lessons from a recent study[1] of long-term growth in Egyptian agriculture over 1961-2016. The study identified how changes in agricultural input use (the amounts of land, water, labor, capital and intermediate inputs), technical change, and efficiency improvements contributed to increasing production of crops, animal products and farm-raised fish. Results show that technical innovations and efficiency gains contributed significantly more to agricultural growth than expansion of water use or irrigated area. Government policies played a critical role through investment in public goods like agricultural research and improved water drainage. Policy reforms in the 1980s that moved Egypt toward a more market-oriented economy also helped accelerate productivity growth in agriculture by improving incentives for producers. The resulting rise in total resource productivity increased the value of natural resource rents (i.e., the private value of irrigated land and the social value of water use) in Egyptian agriculture.

Key Messages

- Technological innovations and efficiency gains have greatly improved productivity in Egyptian agriculture over the past 55 years.
- Over this period, Egypt succeeded in raising agricultural output much faster than the rate at which it expanded irrigated area or water use in agriculture, thereby increasing the productivity of land and water in agriculture.
- Much of the growth in agricultural output was achieved through gains in Total Factor Productivity (TFP), which is a measure of the overall efficiency with which farmland, labor, and capital are used to produce farm products.
- Technical and efficiency improvements also raised Total Resource Productivity (TRP), a measure which includes the social value of irrigation water as an input into farm production.
- Market and prices incentives play an important role in encouraging farmers to adopt new technologies, crops and farming practices to raise productivity and save resources.
- The transition from a state managed (socialist) economy to a market-based economy in the 1980s spurred faster growth in agricultural TFP because reforms enabled farmers to reallocate resources to produce more profitable commodities like vegetables, fruits and farm-raised fish.

1 Fuglie, Keith (USDA-ERS), Boubaker Dhehibi (RALSP-ICARDA), Ali El Shahat (Zagazig University- Egypt), and Aden Aw-Hassan (RALSP-ICARDA). "Water, Policy and Productivity in Egyptian Agriculture." Working Paper, February, 2020. RALSP-ICARDA.

- To maintain TFP growth in agriculture, government investments should focus on high-payoff public goods like agricultural research, farmer extension and training, and improved drainage systems that maintain soil quality and enable the reuse of irrigation water.
- With strong public and private investment in research and innovation, water productivity need not be a binding constraint to future growth in Egyptian agriculture.

Introduction

Where water scarcity poses a significant constraint to agriculture, increasing "water productivity" is essential. In fact, agricultural innovations and productivity growth have been releasing natural resource constraints to growth around the world for nearly a century. Thus, when resource scarcity restricts agricultural production, public investments in research to raise productivity can release constraints on growth. In this brief, we present findings from a study in which we examine the evolution of agricultural and resource productivity in Egypt over 55 years, from 1961 to 2016. To this end, we constructed two Tornqvist-Thiel indexes of total productivity. The first index, total factor productivity (TFP) is based on inputs valued at producer prices, in which water is supplied freely and resource rents accrue to the value of irrigated land. For the second index, total resource productivity (TRP), the cost of public subsidies for irrigation are included as part of the total agricultural inputs contributing to production and resource rents are used to derive the implicit social value of water. Using growth accounting, we identify the respective contributions of expanded irrigation, input intensification, and improved total productivity to aggregate agricultural growth in Egypt.

Results

Between 1961 and 2016, the Tornqvist-Thiel index of output of crops, animal products and farmed fish in Egypt increased from a base value of 100 to 500, or by 400 percent **(Figure 1)**. Annual output growth averaged 3.16 percent, which accelerated from 2.28 percent during the socialist period (1961-1986) to 3.40 percent after market-oriented reforms were introduced in 1986-87. Considering just crops, real output grew by 307 percent over the 55-year period, or at an average annual rate of 2.41 percent.

If agricultural growth is resource-dependent, we would expect resources like land and water to grow at about the same rate as output. But in fact, land and water use grew much more slowly than the 400 percent increase in output. Between 1961 and 2016, irrigated area increased from 2.57 million hectares (mha) to 3.73 mha, or 45 percent. This was closely tracked by water withdrawals for agricultural use, which grew from 44 to 62 billion cubic meters, or 42

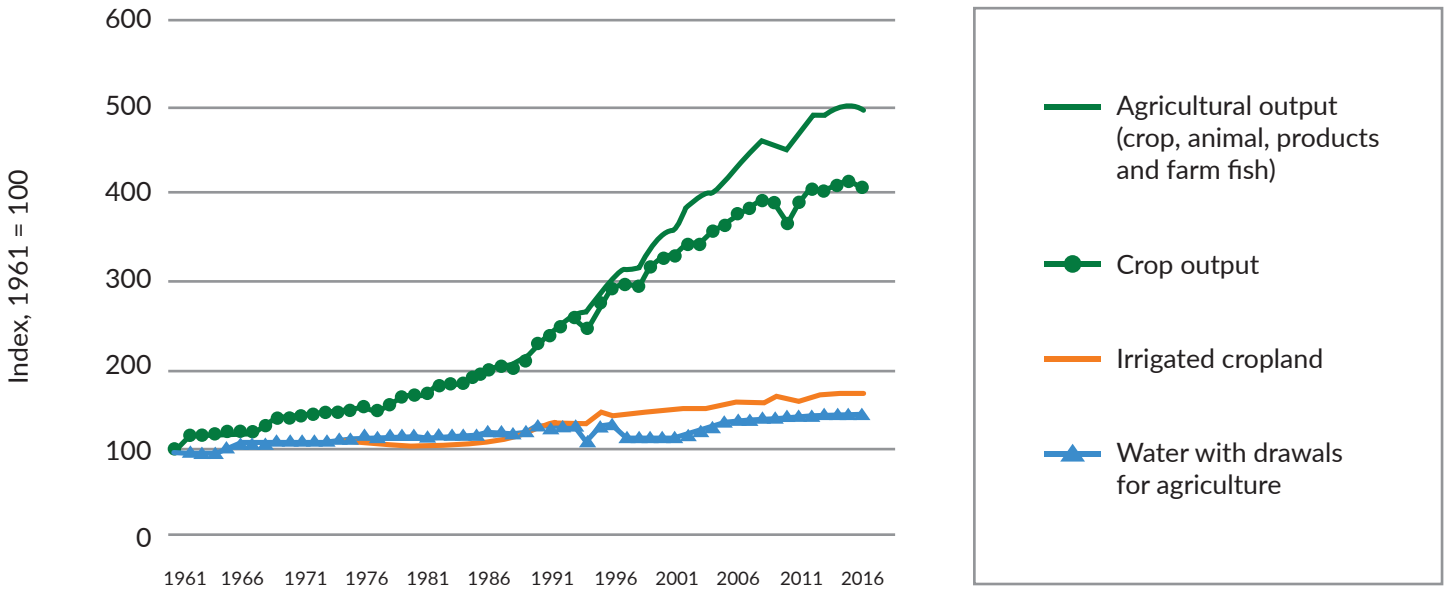

Figure 1. Output, land and water use in Egyptian agriculture

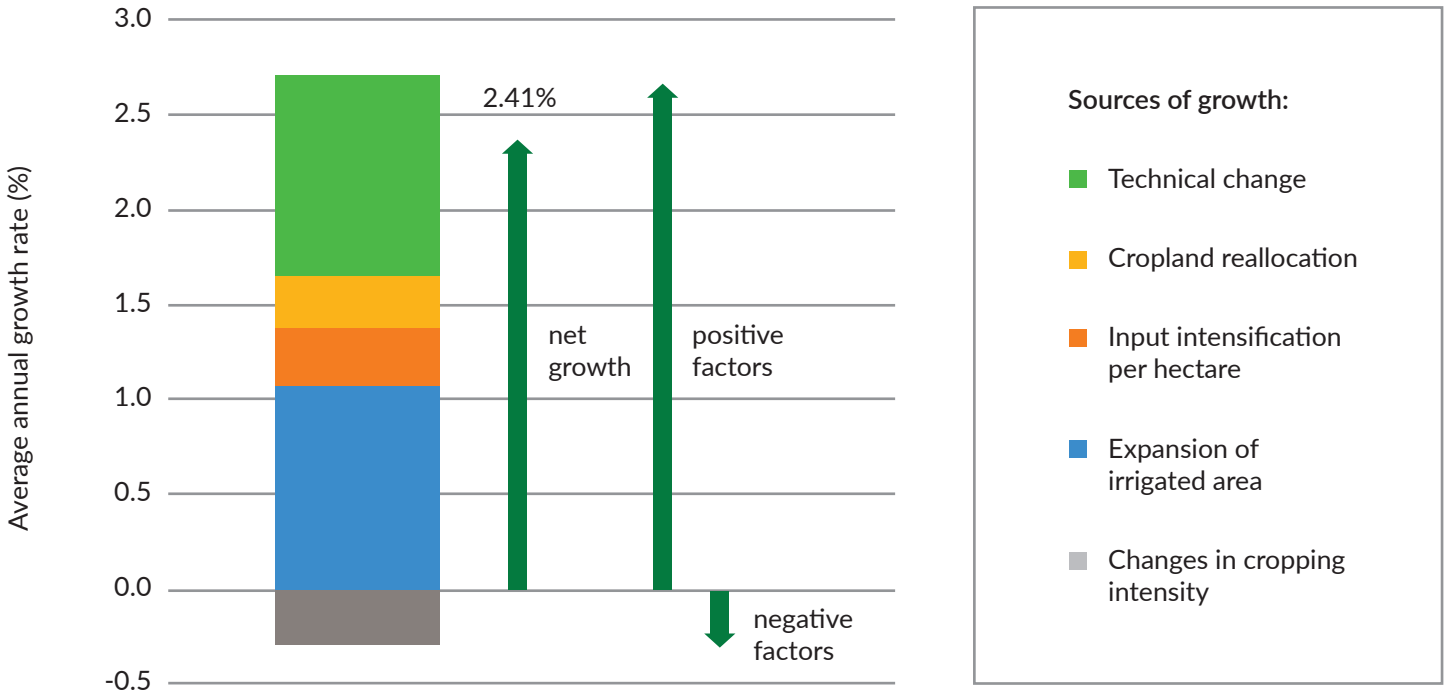

Figure 2: Sources of growth in crop output in Egypt, 1961-2016

percent, over this period (see Figure 1). Overall, Egyptian agriculture over the past 55 years has been dominated by intensive growth (raising output per unit of land and water) rather than extensive growth (extending irrigated area and water use).

Focusing just on the crop sector, the growth in output is decomposed in **Figure 2** into parts attributable to (i) expansion of cultivated area, (ii) technical change, or changes crop "net yield' (that is, increase in harvested yield net of any changes in other input use per hectare), (iii) reallocation of land to more profitable crops, which increases the value of output even at constant prices, and (iv) input intensification, or the use of more labor, capital and intermediate inputs like fertilizers per hectare. Over 1961-2016, only 31 percent of the increase in crop production came from increasing the area harvested (which was slightly less than the growth in irrigated area due to a decline in cropping intensity as a larger share of land was devoted to perennial crops). Technical change (increases in crop net yield) accounted for 44 percent of total crop growth, while reallocation of cropland to more profitable crops like fruits and vegetables was responsible for 12 percent of the increase. The remaining portion of crop growth, 13 percent, was due to intensification of other inputs per hectare harvested.

Despite the overall strong productivity growth exhibited by Egyptian agriculture since 1961, the study found evidence that growth slowed during the 2007-2016 period, especially in crop production. Most of this slowdown can be attributed to a sharp decline in the rate of crop technical change. The rate of crop technical change had actually turned negative (declining by 0.54 percent per year over 2007-2016), although farmers were able to offset this by intensifying use of other inputs and changing their crop mix to continue to raise aggregate crop yield. The negative rate of technical change in crop production could reflect a number of factors: fewer new technologies coming from the research system, emergence of new pests and diseases, changes in climate, or declining quality of irrigation services, such as insufficient or less timely deliveries of water.

This analysis would point to the importance of reinvigorating technical change as an engine of growth in Egyptian crop production, and consequently, these empirical findings demonstrate the importance of technical change, made possible by public and private investments in research and innovation, in raising the output of Egyptian crops.

Concluding remarks and strategic actions

These findings have considerable relevance for agricultural policies in Egypt and other water-constrained countries. The applied model gives explicit attention to the role of the public sector in supplying to agriculture both the water and technology that has driven growth in Egyptian agriculture. The model produces rules governing the optimal allocation

of scarce public resources among these public goods. It provides a means of valuing water that considers not only its marginal contribution to output but also the opportunity cost of capital to deliver water to fields. This opportunity cost could be high if public funds could be better used to supply technology. The empirical results suggest directions for how Egypt might continue to raise agricultural output in the face of increasing constraints on natural resources. This could be achieved through the following suggested strategic actions:

- Increase public investment in agricultural research and extension to continue to develop new technologies that raise total productivity in crop, animal and fish production
- Refocus public investment in irrigation toward rehabilitating existing systems to improve timely water delivery, drainage, and water reuse, rather than new systems to expand cultivated area
- Through public-private partnerships, enhance market value chains for profitable commodities like vegetables, fruits, and farm-raised fish
- Introduce appropriate policies to improve water governance and support water saving crops and techniques
- Consider using land taxes or water users' fees to help finance public investments in agriculture.

Key Findings

- Between 1961 and 2016, Egyptian real agricultural output (holding prices constant while volumes vary) increased by 400 percent, or at an average annual rate of 3.12 percent.
- Over the same period, the amount of irrigated land increased by 45 percent while water withdrawals for agriculture increased by 42 percent. This means that average output per hectare and per cubic meter of water used agriculture increased steadily and significantly.
- The fastest growing component of Egyptian agriculture was farm-raised fish, with its revenue share rising from less than 1 percent in 1990 to 8.2 percent in 2016. Improvements in aquaculture productivity and expansion of supply led to lower fish prices for consumers.
- Improvements in productivity came about mainly through adoption of new technologies and management practices, as well as by reallocating resources to more profitable commodities. Resources devoted to cotton, grain legumes and fodder crops declined while commodities like fruits, vegetables, cereal grains, animal products and fish received more attention from producers.
- Total crop production grew at an average annual rate of 2.41 percent over 1961-2016. About 31 percent of this growth was due to expanding irrigated area while 69 percent was due to raising output per hectare of irrigated land. The increase in average output per hectare was caused by a combination of technical change, efficiency improvement (planting more profitable crops) and input intensification (using more labor, capital and intermediate inputs per hectare). Technical change contributed to about 44 percent of total crop growth, with improved efficiency and input intensification contributing 12 and 13 percent, respectively, to the increase in crop output.
- The increase in farm productivity increased natural resource rents to land and water. Since water is freely provided to producers who hold property rights to land receiving the water, these resource rents accrued to landowners (or renters, if rents are capped by policy). From a social perspective, higher productivity increased the marginal value of water used for irrigation from 190 LE/1000m3 in the 1960s and 722 LE/1000m3 during 2001-2016 (in constant 2005 Egyptian Pounds, or LE), according to the study.
- Agricultural output and productivity growth accelerated following the transition from a socialist to market-oriented economy in the 1980s. The annual growth rate of agricultural output increased from 2.28 percent during 1961-1986 to 3.40 percent during 1987-2016, while the annual rate of growth in Total Resource Productivity increased form 1.31 percent to 1.92 percent.
- Maintaining agriculture growth in Egypt requires robust public investment in agricultural research and extension, improved drainage, and rehabilitation of the existing irrigation infrastructure to assure timely water delivery. These investments appear to have earned a substantially higher return to investment in expanding cultivated area, which has been a major focus in the past.

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