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Water, Policy and Productivity in Egyptian Agriculture

Abstract

When water scarcity restricts agricultural production, expanding water resources is only one option to increase or maintain output; investments in research to raise productivity can also release constraints on growth. In this paper we construct a model of optimal resource allocation with both public and private inputs in production – the public sector invests in research and irrigation infrastructure to supply technology and water, respectively, while the private sector supplies other inputs. The model is used to derive shadow values for water that suggest “crop per drop” valuations are likely to significantly overstate the marginal value of water in agriculture. We apply our model to analyze sources of growth in Egyptian agriculture, which is almost entirely dependent on publicly-supplied irrigation water, over 1961-2016. We construct two indexes of total productivity: total *factor* productivity treats resources from a producer perspective, where water is free and resource rents accrue to land. Total *resource* productivity takes a social perspective, where government subsidies for irrigation are included as a cost of production, and resource rents are assigned to water withdrawals for agriculture. Our results find that technological innovations and efficiency gains contributed significantly more to agricultural growth in Egypt than expansion of irrigated area. Productivity growth accelerated in the 1980s following the transition from a socialist to a market-oriented economy. Including social costs of irrigation provision reduces the implied rate of total productivity growth somewhat. Nonetheless, the rise in total resource productivity significantly increased the value of natural resource rents in Egyptian agriculture.

JEL Classification: Q15, Q16, Q22, Q25, Q56

Keywords: Growth accounting, agricultural capital stock, total factor productivity, total resource productivity, unit resource rent, irrigation and drainage, aquaculture

Water, Policy and Productivity in Egyptian Agriculture

The imminent completion of Ethiopia's Grand Renaissance Dam on the Blue Nile has cast a spotlight on the growing competition for water in the Nile Basin. Egypt in particular sees loss of Nile water as an existential threat. With practically no rainfall, Egypt depends on the Nile for 95 percent of its water resources and uses 80 percent of available water for agriculture (AQUASTAT). While the immediate concern is how fast Ethiopia fills the reservoir (thus reducing the flow downriver), over the longer term the growing demands for Nile water among the river's riparian states (Conniff et al. 2012), as well as threats from climate change (Yates and Strezepek 1996), raise hard questions about the viability of Egyptian agriculture.

To address the growing competition for scarce water in this basin and in other parts of the world, raising "water productivity" in agriculture is seen as essential (Rosegrant, Cai and Cline 2002). Yet water productivity is an elusive concept (Scheierling, Treguer and Booker 2016). Much of the literature on agricultural water management focuses on efficiency – the percentage of applied water that is used by a crop. But because water flows through a system and is often reused multiple times in a water basin, estimates of water efficiency at the basin level can be much higher than efficiency on any particular field. Thus, adopting new types of irrigation systems that raise field-level water efficiency may not have much effect on basin-level water efficiency. Another way of improving water productivity is by switching to crops that require less water or produce a higher valued yield per unit of water applied. But economic models of product substitution and induced innovation rely on scarcity being reflected in relative product and factor prices. Notions like maximizing "crop per drop," lack economic motivation if, as is often the case, water is supplied to producers freely or at highly subsidized rates. Studies of agricultural total factor productivity, which account for rising factor costs in production, have usually ignored water as an input because due to subsidies its share of producer cost is very small, apart from the energy cost of pumping (Scheierling, Treguer and Booker 2016).

This study gives explicit attention to the private and social cost of water in examining the evolution of agricultural productivity in Egypt over 55 years, from 1961 to 2016. A unique feature of Egyptian agriculture is its almost total reliance on irrigation for water. With negligible rainfall, the Nile River and underground aquifers provide nearly all water for crops and animals, as well as for non-agricultural uses. Egyptian policy toward agriculture has emphasized expanding and rehabilitating irrigated areas as a principal means for expanding production. Between 1961 and 2016, irrigated cropland[1] increased from 2.57 million hectares (mha) to 3.73 mha (CAPMAS(a)), while harvested area increased from 4.17 mha to 6.12 mha (FAOSTAT). However, growing competition for available water could severely constrain this pathway for agricultural growth.

The period of our study covers major epochs in Egyptian agricultural and economic policy. Following Egypt's 1952 revolution that ended monarchial rule, the government initially pursued socialist policies, but later adopted market-oriented reforms. Government policy toward agriculture during the socialist years included acreage controls and mandatory crop deliveries to the state at fixed prices (Hazell et al. 1995). The government also introduced land reforms that established caps on land ownership, placed limits on land rents, and granted perpetual (and inheritable) tenure security to tenant farmers (Kassim et al. 2018). Reforms to agricultural policy began in the 1980s. During 1986-87 especially, Egypt relaxed planting restrictions, ended mandatory crop deliver quotas at fixed prices for most crops, and allowed the private sector and market forces a greater role in determining farm resource allocation and choice of crops (Hazell et al. 1995; Kassim et al. 2018). Additional reforms in the 1990s included privatization of state-owned agribusinesses and changes to land laws that ended tenant's tenure security and allowed land rents to rise (Kassim et al. 2018). But throughout the entire period, the government assumed primary responsibility for managing the nation's water use and the agricultural irrigation system.

In addition to expanding irrigated cropland, the Egyptian government has also invested in improving water management and raising productivity on existing croplands. The Ministry of Water Resources and Irrigation has assumed responsibility for installing sub-surface tile drainage in farmers' fields and drainage channels, both to prevent salt accumulation in soils and to enable greater reuse of drainage water down river. The government also invests in improving agricultural technology. By 2012 Egypt had the largest public agricultural research system in Africa, employing over 8,000 researchers and spending $450 million per year (Stads 2015). In the Egyptian context, both water and technology are supplied by the government and provided essentially free to producers.

Our conceptual model analyzes the case where agricultural growth depends on the supply and allocation of both public and private resources. The public sector supplies two goods – irrigation and technology, which producers take as given and choose nonland (or nonwater) inputs like labor and capital to maximize private returns. We use this model to examine the optimal allocation of limited government resources toward each of the inputs it supplies, the tradeoffs and complementarities between them, and their social valuation. Our model suggests that measures like average water productivity ("crop per drop") can significantly overstate the marginal value of water to the sector.

In our empirical application to Egyptian agriculture, we construct Tornqvist-Thiel indexes of agricultural outputs and inputs (both public and private), and use these to construct indexes of total *factor* production, based on inputs valued at producer prices, and total *resource* productivity, which includes the social value of water and public subsidies for irrigation as part of the total agricultural inputs contributing to production. Using growth accounting, we isolate the contributions of expanded irrigation, input intensification, and improved total factor and resource productivity to aggregate agricultural growth.

While we do not in this study estimate returns to various kinds of public investments, our findings shed important insights on policy. Results show that productivity made a substantially larger contribution to raising output than expanding the use of land, water or other factors of production. Our results also show how efficiency changes from reallocating agricultural resources to the production of more profitable commodities contributed to aggregate growth of the agricultural sector. Moreover, technical and efficiency changes accelerated between the "socialist period" (1961-1986) and the "market-oriented period" (1987-2016), suggesting that the long-run rate of productivity growth is responsive to policy reform.

Model of Agricultural Growth with Public and Private Inputs

Let agricultural output Y be produced from a Cobb-Douglas function using irrigated land X_1, non-land inputs X_2, and technology A:

$$Y = A\, X_1^{\beta_1} X_2^{\beta_2},\ where\ \beta_i > 0\ \forall\ i\ and\ \beta_1 + \beta_2 = 1. \qquad \textit{Eq 1}$$

Producers take prices, technology and the area of irrigated land as given and maximize profits by choosing X_2. Technology and irrigated land are supplied by the public sector through investments in research and irrigation capital. The production function is assumed to exhibit constant returns to scale in land and non-land inputs. The supply of X_2 is assumed to be perfectly elastic at price p_2. Output price is normalized to 1 such that p_2 represents the terms of trade between non-land inputs and agricultural output.

The government faces a budget constraint $\bar{G}$ which it can use to invest in research and irrigation. Government investment in research capital R produces non-rival technology according to a technology production function:

$$A = R^{\eta},\ where\ \eta > 0 \qquad \textit{Eq 2}$$

Infrastructure to deliver water to farm fields costs θ dollars ($\theta > 0$) of irrigation capital I per hectare, so the amount of land supplied to agriculture is $X_1 = I\theta^{-1}$. Substituting these relationships into the agricultural production function gives:

$$Y = R^{\eta}\ (I\theta^{-1})^{\beta_1} X_2^{\beta_2} \qquad \textit{Eq 3}$$

Besides the budget constraint of $\bar{G}$ (i.e., $R + I\ \leq \bar{G}$, with $\bar{G} \geq 0$), total water available for irrigation is also limited to $\bar{W}$. Each hectare of land sown to crops is assumed to need a certain quantity ϕ of water, which includes water for crop consumption as well as storage and delivery losses of the irrigation system. Thus, the water constraint is given by $\phi X_1\ \leq \bar{W}$, with $\phi > 0$ and $\bar{W} \geq 0$. The water constraint can also be written in terms of irrigation capital as $\phi\theta^{-1}I\ \leq \bar{W}$ (substituting $I\theta^{-1}$ for X_1).

The social planner's problem is to maximize total surplus S subject to the budget and water constraints. The Lagrangian for this constrained optimization problem is:

$$S(I,R,X_2) \;=\; R^{\eta}\,(I\theta^{-1})^{\beta_1}X_2^{\beta_2} - \;p_2X_2 + \;\lambda_1(\bar{G} - R - I) + \;\lambda_2\big(\bar{W} - \;\phi(I\theta^{-1})\big) \quad \textit{Eq 4}$$

where $\lambda_1$and λ_2 are lagrangian multipliers. λ_1 is the marginal social value of the government budget and $\lambda_2$indicates the marginal social value of water for agriculture. These will have positive values if the constraints are binding and zero otherwise.

Kuhn-Tucker conditions for the social planner's problem are:

$$\frac{\partial S}{\partial X_2} = \;\beta_2\left(\frac{Y^*}{X_2^*}\right) - \;p_2 = 0 \qquad \textit{Eq 5i}$$

$$\frac{\partial S}{\partial R} = \;\eta\left(\frac{Y^*}{R^*}\right) - \;\lambda_1 = 0 \qquad \textit{Eq 5ii}$$

$$\frac{\partial S}{\partial I} = \;\beta_1\left(\frac{Y^*}{I^*}\right) - \;\lambda_1 - \;\lambda_2\left(\frac{\bar{W}}{I^*}\right) \;= 0 \qquad \textit{Eq 5iii}$$

where the stars ("*") represent surplus-maximizing quantities. Note that when all available water is used for irrigation, then by definition $\phi\theta^{-1} = \bar{W}/I^*$. In other words, $\phi\theta^{-1}$ equals the average capital cost of delivering one unit of water for irrigation.

The social planner's optimal choice of non-land inputs is the same as the profit-maximizing choice for private producers, and gives the well-known condition where the cost share of X_2 equals the production elasticity β_2:

$$\frac{p_2\,X_2^*}{Y^*} = \;\;\beta_2 \qquad \textit{Eq 6}$$

The optimal public investment in irrigation and research, respectively, satisfy

$$\lambda_1 \;=\; \frac{\eta Y^*}{R^*} \qquad \textit{Eq 7}$$

and

$$\lambda_1 + \lambda_2\left(\frac{\bar{W}}{I^*}\right) = \frac{\beta_1 Y^*}{I^*} \qquad \textit{Eq 8}$$

Under an optimal solution the government budget constraint will always be binding, so $\lambda_1 > 0$. But it is possible that water could be so plentiful that the available budget is insufficient to fully utilize it, in which case the water constraint would be nonbinding and $\lambda_2 = 0$. Although technology and land (i.e, research and irrigation capital) are substitutes in the production function, an increase in one increases the marginal product of the other. Thus an increase in research capital would increase the marginal returns to irrigation capital (as well as non-land inputs X_2). Similarly, an increase in irrigated area would increase returns to research. Under an optimal solution an increase in either capital stock would draw in larger amounts of the other public and private inputs.

Consider first the case where only the budget constraint is binding. Then $\lambda_1 > 0$ and $\lambda_2 = 0$. In this case the second and third Kuhn-Tucker conditions (Eq 7 and Eq 8) imply:

$$\lambda_1 = \eta\left({Y^*}/{R^*}\right) = \beta_1\left({Y^*}/{I^*}\right) \qquad \textit{Eq 9}$$

This condition says that the optimal combination of public goods requires that their marginal products (returns) be equal. In a Cobb-Douglas production function, the optimal ratio between research and irrigation capital is the ratio of their respective production elasticities $\left(i.e., {I^*}/{R^*} = {\beta_1}/{\eta}\right)$. Using this relation and the budget constraint ($\bar{G} = R + I$) yields a direct solution for the optimal choice of research and irrigation capitals in terms of $\bar{G}, \eta$ and β_1:

$$I^* = \left(\frac{\beta_1}{\beta_1+\eta}\right)\bar{G} \quad \textit{and} \quad R^* = \left(\frac{\eta}{\beta_1+\eta}\right)\bar{G} \qquad \textit{Eq 10}$$

If both constraints are binding, then the Kuhn-Tucker conditions imply:

$$\lambda_1 = \eta(Y^*/_{R^*}) > 0 \qquad \textit{Eq 11i}$$

and

$$\lambda_2 = \left(\frac{I^*}{\overline{W}}\right)\left[\frac{\beta_1 Y^*}{I^*} - \frac{\eta Y^*}{R^*}\right] > 0 \qquad \textit{Eq 11ii}$$

Eq 11ii can be rewritten as:

$$\lambda_2 = \left(\frac{Y^*}{\overline{W}}\right)\left[\beta_1 - \eta\frac{I^*}{R^*}\right] > 0 \qquad \textit{Eq 12}$$

which gives the marginal value of water as the average output per unit of water ($Y^*/\overline{W}$, or "crop per drop") times the terms in the parenthesis. Note that this term $\left[\beta_1 - \eta\frac{I^*}{R^*}\right]$ is bounded above by β_1 (since all the parameters have nonnegative values), or the cost share of land. This simply says that the value of an additional unit of water (or another hectare of irrigated area), is no greater than the additional output from that water net of the cost of nonland production inputs. The marginal value of water is further attenuated by the opportunity cost of foregone research when public funds are diverted from research to irrigation. The marginal value of water will likely be substantially less than its average "crop per drop," according to Eq 12.

Once all available water is used, no further investment in irrigation is profitable, and any additional budget is allocated to research. In this case, the marginal product of irrigation begins to exceed the marginal product of research (since $\lambda_2 > 0$ requires that $\beta_1 {Y^*}/_{I^*} > \eta {Y^*}/_{R^*}$). As more technology is produced, the marginal product of research declines while the marginal product of water rises, widening the gap between the marginal values of water and research. It may eventually even become profitable for the government to divert research spending to developing new sources of water supply if that is a possibility. Nevertheless, with two forms of public capital available, the government has the option of raising output through research even as limits to water are reached.

Figure 1 illustrates the optimal allocation of the public goods under the budget and water resource constraints. Research spending is given on the X-axis, and $R = \bar{G}$ is feasible if all of the available government budget is spent on research. Irrigation investment is given on the Y-axis. While it is possible to build out the irrigation system as far as $\bar{G}$, there is sufficient water to only irrigate $\overline{W}$. Maximum output is obtained at the tangency of the feasibility set and the marginal rate of technical substitution (MRTS) between the two public goods (the slope of the isoquant Y_1). Point A represents a solution where only the budget constraint is binding and I_A is invested in irrigation while R_A is allocated to research. Here, MRTS equals 1, implying that the marginal product of irrigation (MP_I) equals the marginal product of research (MP_R). Point B is a case where both the budget and water constraints are binding. Once opportunities to expand irrigation have been exhausted, any further budgetary resources are allocated to research, which lowers its marginal product. Thus, at B, $MP_R < MP_I$. Points C and D represent suboptimal allocations of the public goods. At C, the government has expanded the irrigation system beyond what available water can supply, and some land that is equipped for irrigation ends up dry. At point D, excessive investment is made in research.

Figure 2 depicts the model from the producer's perspective. Taking technology A and irrigated area $\overline{X_1}$ as given and water as free, farmers chose $X_2$to produce $Y$and maximize profits. The profit mazimizing level of $X_2$is shown as the intersection between p_2 and MP_{X_2}, the marginal product of X_2. Profits are shown by the shaded region $S = Y - p_2X_2 = p_1X_1$, where $p_1$is the per hectare resource rent accruing to holders of the property rights to land. An investment in research shifts the production function from Y to Y'. The profit-maximizing level of X_2 shifts from $\overline{X_2}$ to $\widehat{X_2}$, output increases from $\bar{Y}$ to $\hat{Y}$, and total surplus (profit) increases by the shaded region labeled ΔS. In the case of a research-induced production shift, rents to land rise such that $p_1' = (S + \Delta S)/X_1$, and the current land owners capture the welfare gains of the production shift. If the water constraint is not binding, there is an equivalent public investment in irrigation (expanding the irrigated area from X_1 to X_1') that would also shift the production function from Y to Y'. In this case, land rent would remain at p_1 and the increase in the surplus ΔS would accrue to whomever the property rights of the newly irrigated land are assigned. If this land is sold or taxed by the government at market rates, then this surplus would accrue to the government.

Empirical Application to Egyptian Agriculture

We use growth accounting methods (Fuglie 2015) to examine sources of growth in Egyptian agriculture. Using the assumption of constant returns to scale in inputs X_1 and X_2 (i.e., that $\beta_1 + \beta_2 = 1$), we can rewrite the production function in Eq (1) as:

$$Y = A\, X_1^{\beta_1} \left(\frac{X_2}{X_1}\right)^{\beta_2} X_1^{\beta_2} = AX_1 \left(\frac{X_2}{X_1}\right)^{\beta_2} \qquad \textit{Eq 13}$$

Taking the log of Eq(13) and differentiating with respect to time yields the Solow-type growth equation:

$$\frac{\partial ln\,(Y_t)}{\partial t} = \frac{\partial ln\,(A_t)}{\partial t} + \frac{\partial ln\,(X_{1t})}{\partial t} + \beta_2 \frac{\partial ln\left({}^{X_{2t}}/_{X_{1t}}\right)}{\partial t} \qquad \textit{Eq 14}$$

Under profit maximization we can replace β_2 with the cost share of X_2, which we call $\sigma_2 \equiv {}^{p_2 X_2}/_{Y}$. Allowing for Y and X_2 to be vectors consisting of multiple goods, the Tornqvist-Thiel index method provides for the following output growth decomposition:

Eq 15

$$\sum_{j=1}^{m}\left(\frac{R_{jt}+\ R_{jt-1}}{2}\right)\ln\left(\frac{Y_{jt}}{Y_{jt-1}}\right)\ =\ \ln\left(\frac{A_t}{A_{t-1}}\right)+\ln\left(\frac{X_{1t}}{X_{1t-1}}\right)+\sum_{i=2}^{n}\left(\frac{\sigma_{it}+\ \sigma_{it-1}}{2}\right)\ln\left(\frac{X_{it}/X_{1t}}{X_{it-1}/X_{1t-1}}\right)$$

where R_j is the revenue share of the jth of m outputs, there are n inputs, of which the cost share of land is $\sigma_1 = 1 - \sum_{1=2}^{n}\sigma_i$, which implies that the rental price of land is $p_1 = (Y - p_2X_2)/X_1$. Between any two periods, the average revenue and cost shares are held fixed while quantities vary. The left-hand-side term of Eq (15) give the growth rate in aggregate output. The right-hand-side terms of Eq (15) decompose output growth into changes in total productivity (the change in A), irrigated land area (the change in X_1), and per hectare intensity of non-land inputs (the change in X_i/X_1), respectively. Growth in total productivity is measured as the difference between output growth and input growth, and thus captures the combined effects of all the factors that influence productivity and efficiency. This includes not only adoption of new technologies, but also improvements in the allocative or technical efficiency of resource use and economies of scale.

An innovation of this study is to consider total productivity from both private and social perspectives. Using producer prices to value outputs and inputs, we derive an index of total *factor* productivity (TFP). In this derivation, water and the public investment in the water distribution system are considered to be free inputs, and net revenue (gross revenue minus factor costs) is treated as an implicit factor payment to land. Valuing inputs at their social cost, including public subsidies for irrigation and water, we derive an index of total *resource* productivity (TRP). To value the environmental services from water use in agriculture, we derive its (implicit) unit resource rent, or shadow value, from the perspective of producers

(Brandt, Schreyer and Zipperer 2016). In this formulation, land is treated as a free input (valueless to agriculture in the absence of water) and the unit resource rent of water is net agricultural revenue per cubic meter of water withdrawn for agricultural use.[2] Because technology is a non-rival good, government spending on research is not included in private or social cost accounting. Rather, economic surplus from research-induced technical change is either captured by producers as rising rents to fixed resources (land or water), or passed on to consumers in the form of lower commodity prices.

Data on agricultural outputs, inputs, and their prices are primarily from the Central Agency for Public Mobilization and Statistics (CAPMAS), the official statistical agency of Egypt, and supplemented with data from other Egyptian government agencies, the United Nations (FAO and ILO), the U.S. Department of Agriculture, and the World Bank. Outputs include crops, animal products, and farm-raised fish. Crops consist of grains, oilseeds, sugar crops, vegetables, nuts, fruits, and fodder crops (an input into animal production). Animal outputs include meat, milk, eggs, honey, and manure (an input for crops). Fish raised in farm ponds and cages are also part of the outputs but wild catch from fresh water or seas is excluded. Inputs include irrigated cropland, water used for agriculture, adult labor (male and female), private capital (structures and ponds, farm machinery, livestock inventories, and fruit and nut-bearing trees), public capital in irrigation infrastructure, intermediate inputs (seed, fertilizers, pesticides, animal feed, and fuel) and the public and private costs of operation and maintenance (O&M) of the irrigation system. For agricultural labor, we make a correction to national labor force surveys which appear to have significantly undercounted female workers in agriculture prior to 1990. For capital, we use the perpetual inventory method to construct estimates of capital stock from past investments. For this we are able to draw upon Radwan (1973), who compiled investment series for Egyptian agriculture dating back to the 19th Century. For capital produced by farms (i.e., livestock and trees), we estimate capital stock using methods proposed by Larson et al. (2000), except that we fix values using 1960 prices (adjusting these only for general inflation), to put them in constant-quality units. Thus, improved technology embodied in these inputs (which would inflate their real market value) will be captured as growth in total productivity and not as growth in the input.

Because we account for crop and animal outputs that are used as inputs in the other sector, we are able to derive separate output, input, and TFP indexes for each sector. Intermediate inputs used in crop production include fertilizers, manure, pesticides, crop seed, and fuel expenses, while feed, fodder, hatchling and fish fry expenses are assigned to animal-fish production. Capital services for crops include farm machinery and fruit trees, while capital services from farm structures and fish ponds are allocated to animal-fish production. For labor, we assume that value-added per worker is equalized between subsectors and allocate labor in proportion to the value-added contributions of each sector to total agriculture. The net revenues of each sector are assigned as implicit payments to land. With separate estimates of TFP growth for aggregate crop production, we further explore how increases in net yield of individual crops (technical change) and changes in cropland allocation among crops (efficiency changes) each contributed to the growth of TFP.

A full description of data sources and constructs is given in the Appendix.

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 3). Annual output growth averaged 3.16 percent, accelerating 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 and animal products, real output grew by 321 percent over the 55-year period.

Because the Tornqvist-Thiel index is a chained index using varying weights (i.e., revenue shares) over time to aggregate quantities of different commodities, it is considered to be a more accurate description of growth than fixed weight indexes (Caves, Christensen and Diewert 1982). For example, using fixed revenue shares from 2004-2006 to aggregate quantities gives an estimate of 373 percent growth over 1961-2016, or 2.96 percent per year. One reason for the lower growth estimate is that due to rapid productivity growth in farm-raised fish, the producer price of fish fell sharply relative to other commodities, and using the relatively low 2004-2006 price understates the contribution of farmed fish to total growth in earlier years. Another advantage of our Tornqvist-Thiel index is that it is based on domestic producer prices. The FAO index of gross agricultural output (GAO) aggregates the quantities of crop and livestock products using fixed international average prices from 2004-2006. According to this index, Egyptian crop and livestock production grew by 3.23 percent per year, so that by 2016 output was 390 percent above 1961 levels.[3] Using the same set of commodities (i.e., excluding farmed fish and fodder crops), the Tornqvist- Thiel index gives a slower rate of growth, 3.00 percent per year, for total growth of 356 percent over 1961-2016. The reason for the upward bias in the FAO output index is because it assumes higher relative prices for vegetables. As vegetables have been a particularly fast-growing part of Egyptian agriculture, the higher weights assumed by FAO exaggerates their role in Egypt's agricultural growth. Nonetheless, all of these indexes agree that there was a significant acceleration in growth after market oriented reforms were introduced in the 1980s.

Figure 3 also shows trends in aggregate land and water use. 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 percent, over this period (Table 1).[4] 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).

Another feature of Egyptian agriculture over the last several decades has been significant changes in commodity composition. Among commodity groups, farm-raised fish was the fastest growing component of output, with its revenue share rising from less than 1 percent prior to 1990 to 8.2 percent in 2016 (see Appendix Tables for detailed figures). The revenue share of animal products also increased. While the crop share of output declined (from about three-quarters in the 1960s to just over half of the gross output in 2016), it also changed in composition. Since the 1960s, area harvested of cotton, grain legumes, and fodder crops fell while area in cereal grains, sugar cane, and fruits and vegetables increased (Table 1).

Horticultural crops in particular have seen impressive growth. The share of irrigated area in tree crops increased from just 3 percent in 1961 to more than 17 percent in 2016, while the share of harvested area from vegetables grew from 6 percent to 15 percent over this period. Cotton, long the main export commodity of Egypt, had by the early years of this Century almost disappeared from the Nile Valley.

Driving the shifts is commodity composition has been changing relative profitability, resulting from changes in market demand, comparative advantage in trade, differential rates of productivity growth across commodities, and policy reforms that enabled greater responsiveness to market incentives. The 1986-87 policy reforms were particularly important: they ended requirements that farmers grow certain crops and deliver their harvests to state agencies at below-market prices (Hazell et al. 1995; Kassim et al. 2018). Instead, private markets were allowed to operate and farmers could choose which crops to grow. However, to some extent the state still exerts influence over cropping decisions through its provision of services, such as credit and water. The supply of irrigation water, for example, is determined by the Ministry of Water Resources and Irrigation (MWRI) in coordination with local Water Users Associations (WUA) based on the predominant cropping pattern in a local area. Individual farmers who diverge from this cropping pattern may find themselves with insufficient water at critical times (Barnes 2014). One reason for the decline in cotton area, for example, has been a state policy to limit water use per hectare (by restricting the hours when irrigation is allowed), as cotton is an especially water-intensive crop. Discouraged from growing cotton, many farmers switched to more high valued products, such as fruits and vegetables, which are less demanding in water needs and where Egypt has a comparative advantage in trade. While Egypt runs a large negative trade balance in food and agricultural products, since 2004 Egypt has been a significant net exporter of horticultural crops (UN COMTRADE).

A constant of Egyptian agricultural policy during both the socialist and market-oriented periods has been substantial subsidies for irrigation. As recently as 2002, government investment in agriculture (almost all of which is for irrigation and drainage) accounted for more than 10 percent of all public investment and 5.5 percent of total national (public and private) investment (Central Bank of Egypt). The construction of the Aswan High Dam in the 1960s stabilized water flow and enabled year-round irrigation to expand throughout the lower Nile valley and delta. Through the construction of an elaborate system of barrages, canals, and regulators, Nile water is delivered to agricultural fields. Water is provided free of charge and while there are no volumetric measures of field-level water use, water use is regulated by restricting withdrawals by each farmer to specific hours of the week (Barnes 2014). Besides the water delivery system, considerable public investment has also been made in drainage. The government has taken responsibility for installing sub-surface tile drains to carry excess water to drainage channels where it can be recovered for further downriver uses (Arab Republic of Egypt, 2005). By 2016, two-thirds of irrigated cropland was served by sub-surface tile drainage (CAPMAS(b)).

Based on long-term times years of annual spending and taking into account capital depreciation (see Appendix for details), we estimate that by 2005 public investment in irrigation and drainage in Egypt had created capital stock worth nearly $6,000 per hectare of irrigated land. This estimate for capital investment in the Egyptian irrigation system matches fairly closely direct estimates of irrigation capital costs for this part of the world. In a review of more than 300 World Bank irrigation projects carried out since 1970, Inocencio et al. (2007) estimated that the average capital cost (in 2005 US$) for irrigation in developing countries was $5,640/ha, and $7,089/ha in the North Africa-West Asia region. Moreover, our estimates indicate that irrigation capital stock per hectare in Egypt rose over time, from (in constant 2005 US$) about $1,600/ha in the 1960s until stabilizing at around $6,000/ha after 2005. The increasing amount of irrigation capital per hectare could reflect both rising costs of extending irrigation to new areas and quality improvements to existing irrigated land, such as the installation of sub-surface drainage. It is also possible that our assumptions about the lifespan (60 years) and depreciation rates (2 percent per year) for irrigation infrastructure are too conservative, and that an increasing share of current investment is for replacing dilapidated capital rather than creating net additions to capital.[5]

How much did public investment in irrigation contribute to Egyptian agricultural growth? For one, it enabled irrigated area to expand by 45 percent since 1961. Second, improved drainage contributed to raising crop yields and preventing salt accumulation in soils on existing irrigated areas. In a growth accounting framework, the contribution of factor accumulation to output growth is based on the observation of input cost. It assumes a profit-maximizing equilibrium, where we can infer the marginal product of an input by observing its marginal cost. However, suppose that public investment is motivated not to maximize profits or producer surplus but for political objectives, such as for national food self-sufficiency or to generate rural employment. If such political considerations result in low economic returns to public investment (i.e., such that observed capital costs exceed the marginal product of capital), then growth accounting could overstate its contribution to the growth of output.

While estimating returns to public investment is beyond the scope of this study, available evidence suggests that these returns have been uneven. Investment in land reclamation (expansion of the area under irrigation) is thought to have earned low returns (Ikram 1980; Fan et al. 2006), while investment in sub-surface drainage appears to have earned favorable returns (Ali, van Leeuwen and Koopmans 2001; van Achthoven et al. 2004). Public spending on agricultural research and rural education (not included in the capital investment data) is also thought to have earned high social returns (Fan et al. 2006).

Besides public capital, producers have invested in private capital in the form of farm structures and ponds, agricultural machinery, livestock, and fruit-bearing trees. Since the early 1960s, the value of public capital stock in irrigation and drainage infrastructure has exceeded total private capital stock by a wide margin (Figure 4).[6] Annual investment by the public and private sectors was roughly equal until the late 1990s, after which public investment in agriculture fell sharply in real terms. But because public investment was in the form of longer-lived assets, its contribution to total accumulated capital stock continued to grow. The share of social capital created through public investment increased from about one-half in 1961 to nearly three-quarters by 2016. For our present purpose, we assume that public and private capital expenditures reflect optimizing behavior so that marginal costs approximate marginal products, on average. Nonetheless, we should keep this assumption in mind in interpreting results.

Table 2 shows the evolution of cost shares for capital and other inputs by decade since 1961. While capital services paid by farmers stayed between 5-6 percent of total costs, the implied cost of social (public and private) capital amounted to about 13.5 percent of total costs (or revenues). The cost share of intermediate inputs averaged nearly 40 percent, while labor accounted for about 12 percent of total costs. The largest components of intermediate inputs are crop fertilizers and animal feeds. Over time, animal feeds was increasingly composed of concentrates rather than roughages, and crop nutrients were increasingly supplied by chemical fertilizers rather than animal manure (see Appendix Tables for detailed information).

In Table 2, the residual profit after other inputs are paid is assigned to the natural resource inputs, land and water. From a farmer's perspective, irrigated land is in fixed supply, water is free and residual profits accrue to land owners (or renters, if rents are held fixed by government policy). The share of total agricultural revenues accruing to land increased from 37-39 percent during 1961-1990 to nearly 50 percent after 2001. The implied land rent rose from 4,460 LE/ha in the 1960s to 14,400 LE/ha after 2001 (constant 2005 LE), a likely contributing factor to the changes to land tenure laws that relaxed caps on land rental rates in the 1990s. Including the cost of public subsidies for irrigation and assigning residual profits to water gives an implied value for water. This implicit value of water rose from 190 LE/1000 m^3 in the 1960s to 722 LE/1000 m^3 during 2001-2016 (constant 2005 LE). The rising rents to land and water reflect the increasing productivity of these resources resulting from technical change and efficiency improvements in farm production.

Our estimate of a marginal value of water of 722 LE/1000 m^3 measures the increase in profit (or producer surplus) from an additional 1000 m^3 of water for agricultural production (or conversely, the compensation that would need to be paid to keep producer welfare neutral if irrigation water was reduced by 1000 m^3). Recall from our constrained optimization model that the marginal value of water is given by $\lambda_2 = \left(\frac{Y^*}{\overline{W}}\right)\left[\beta_1 - \eta \frac{I^*}{R^*}\right]$. The first part of this valuation,

$\lambda_2 = \left(\frac{Y^*}{\bar{W}}\right)[\beta_1]$, is the resource rent to water assuming technology is supplied freely, and corresponds to the value of 722 LE/1000 m^3 derived here. This estimate is within the range of estimates from other studies that have valued water resource rents in Egyptian agriculture. El Gafy et al. (2013), using crop budgets to derive residual profit and assigning that profit to water, estimated an average value to water of 650 LE/1000 m^3. Bader (2004), using a linear programming model of the Egyptian agricultural sector, found the average shadow value of water to be 918 LE/1000 m^3 (varying monthly from a low of 0 to high of 5,750 LE/1000 m^3 in November).[7] But none of these estimates take into account the opportunity cost of foregone productivity from other public investments in agriculture such as research. [8]

Turning to total productivity, Table 3 presents the output, input, TFP and TRP indexes. Overall, aggregate private inputs grew at a trend trade of 1.76 percent per year, implying annual TFP growth of 1.40 percent. Including public subsidies for irrigation raises the (social) input growth rate to 1.85 percent per year, corresponding to a lower annual growth rate in TRP of 1.31 percent. Following the 1986-87 policy reforms, the growth rate in both TFP and TRP accelerated. Since 1987, about 60 percent of increase in agricultural output in Egypt can be attributed to improvements in total productivity.

Table 3 also presents indices of TFP for the crop and the animal-fish sectors. TFP growth in the animal-fish sector was especially strong in the post-reform period (average 2.88 percent per year), led by the dramatic increase in production of farm-raised fish. Improvements in the quality of seed stock, feed concentrates, and fisheries management led to high yields and gains in feed conversion efficiency. Average harvest from fish ponds rose dramatically from around 0.4 tons/ha in the 1980s (Salem and Saleh 2010) to 8.8 tons/ha by 2016 (GAFRD 2018). Part of this productivity increase was passed on to consumers as fish prices fell relative to the general price level (see Appendix Tables for price indexes). However, over the last decade of the series (2007-2016), there was a significant slowdown in both output and productivity growth in the crop and animal-fish sectors. Crop TFP growth had actually turned negative, while TFP growth in the animal-fish sector had fallen to just 1.43 percent per year.

The growth accounting framework sheds light on sources of the crop productivity slowdown that has emerged in recent years, by decomposing growth into resource intensification, technical and efficiency changes. Let aggregate crop production be denoted by Y_c, irrigated land by A_c, and harvested area by A_H. Then the contributions to growth from changes in irrigated area, cropping intensity, and the aggregate value of yield per hectare harvested can be decomposed as

$$\dot{Y}_c = \dot{A}_c + \dot{\left(\frac{A_H}{A_c}\right)} + \dot{\left(\frac{Y_c}{A_H}\right)} \qquad \textit{Eq 16}$$

where the dots above the terms signify their growth rate. Letting $i = 1,2,..c$ indicate individual crops, Fuglie (1991) showed that aggregate crop growth can be decomposed into a part due to increases in individual crop yield and a part resulting from changes in the land share allocation among crops:

$$\dot{Y}_c = \dot{A}_c + \dot{\left(\frac{A_H}{A_c}\right)} + \sum_i \left[R_i \dot{\left(\frac{Y_{ci}}{A_{Hi}}\right)} + R_i \dot{\left(\frac{A_{Hi}}{A_H}\right)} \right] \qquad \textit{Eq 17}$$

where $R_i$is the revenue share of the ith crop in total crop revenue. While we do not have crop-specific accounts to examine changes in input intensification by crop, we can use Eq 15 to account for changes in input intensification (more land, capital and intermediate inputs per hectare harvested) across all crops. Thus, growth in aggregate crop yield per harvested hectare is decomposed into parts due to (i) input intensification,(ii) reallocation of land to more profitable crops and (iii) technical change, or changes crop "net yield' (that is, increases in harvested yield net of any changes in other input use per hectare) holding land allocation fixed.[9]

The results of this growth decomposition for the Egyptian crop sector are shown in Table 4. Over 1961-2016, 69 percent of the growth in crop output came from raising the average value of yield per area harvested and 31 percent from increasing the area harvested. The increase in area harvested 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 (which, by convention, are counted as being harvested only once per year). Reallocation of cropland to more profitable crops like fruits and vegetables was responsible for 12 percent of the increase in aggregate crop output, while increases in crop net yield accounted for 44 percent of total growth. The remaining portion of crop growth, 13 percent, was due to intensification of other inputs per hectare harvested.

Turning now to the 2007-2016 period, the growth decomposition in Table 4 indicates that most of the slowdown in crop output growth 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 (see Barnes, 2017, for evidence that this latter factor is becoming a growing concern in portions of the Nile Valley). This analysis would point to the importance of reinvigorating technical change as an engine of growth in Egyptian crop production.

Conclusions and Implications

This study incorporated water as a factor in the social cost of agricultural production in Egypt, a country almost entirely dependent on irrigation for its agricultural water supply. The cost of water includes not only an implicit resource rent, but also the direct outlays of public funds for the construction and upkeep of irrigation and drainage infrastructure. Using a growth accounting framework, we decomposed the contribution of increasing the supply of irrigation, other factors of production, and the total productivity of these factors, to real growth in agricultural output in Egypt over 1961-2016. We showed that treating inputs from a producer's perspective, where water is a free good and resource rents accrue to land, overstates the growth in total productivity. However, even when the social costs of irrigation investment and water are taking into account, Egypt nonetheless achieved impressive gains total resource productivity over these years. In fact, improvements in TRP accounted for 41.5 percent of the growth in the real output of crops, animal products and farm-raised fish since 1961, and 56.5 percent of output growth since market-oriented policy reforms were introduced in 1986-87.

Our theoretical model gives explicit attention to the role of the public sector in supplying to agriculture both water and technology. The model produces rules governing the optimal allocation of scarce public resources among these goods. It provides a means of valuing water that takes into account 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 earn higher returns by supplying improved technology.

The empirical application to Egyptian agriculture gave results that are highly relevant for policy. One implication is that the growing competition for water in the Nile Basin need not be a constraint to agricultural growth. Between 1961 and 2016, agricultural output in Egypt increased by 400 percent while water withdrawals for agriculture grew by only 42 percent, due entirely to the expansion of irrigated area. Even after taking into account public and private investments in capital, labor, and intermediate inputs, the growth in total resource productivity accounts for a far larger share of output growth than natural resource expansion (with growth attribution shares of 41.5 percent for total resource productivity, 40.8 percent for factor inputs, and 17.7 percent for natural resource expansion). A second important finding is that Egyptian producers were able to raise productivity not only by adopting new technologies but also by shifting resources to more profitable commodities, especially horticultural crops and farm-raised fish. This improvement in allocative efficiency was incentivized by policy reforms that allowed producers greater flexibility in choosing what crops to grow and receive market-determined prices for their products. Between 1987 and 2016, the share of Egypt's harvested cropland in tree and vegetable crops increased from 17 percent to 26 percent while the revenue share from aquaculture grew from less than 1 percent to 8.2 percent. A third finding from this study is that the increase in total resource productivity raised natural resource rents. Because water is supplied freely to producers who hold property rights to the lands receiving the water, rents from productivity growth accrued to the owners of land (or to renters, if rents are capped by policy). From a social perspective, productivity growth increased the marginal value of water in agriculture. The estimated unit resource rent of water increased (in constant 2005 LE) from 190 LE/1000 m^3 in the 1960s to 722 LE/1000 m^3 during 2001-2016.

The growth of resource rents suggests a means by which governments might finance public investment to supply water and technology, i.e., through land or water taxes. While water fees are often advocated in order to incentivize farmers to improve field-level water use efficiency, at the basin level such taxes might not save much water.[10] Collecting land taxes is likely to be much less costly to administer while generating similar amounts of revenue to fund innovations that can yield real resource savings per unit of output.[11]

In fact, throughout history the fundamental role of innovation and productivity in agriculture has been to release resource constraints to growth. The results from this study suggest that the growing competition for water among the riparian states of the Nile Basin need not lead to agricultural stagnation or decline. Rather, a strategy that focuses on raising agricultural productivity can maintain growth even as water use becomes increasingly constrained. By investing more in agricultural research and farm extension and education, improving the quality of irrigation and drainage, and allowing market forces to incentivize greater efficiencies in resource allocation, Egypt and other countries of the region may continue to grow their agricultural sectors even if supplies of natural resource inputs like irrigated land and water decline.

References

Aboulnaga, I. Siddik, W. Megahed, E. Salah, S. Ahmed, R. Nageeb, D. Yassin and M. Abdelzaher. 2017. *Study on Small-Scale Family Farming in the Near East and North Africa Region, Focus Country: Egypt*. Published by FAO, CIHEAM-IAMM and CIRAD, Cairo, Egypt.

Ali, A.M., H.M. van Leeuwen, and R.K. Koopmans. 2001. “Benefits of Draining Agricultural Land in Egypt: Results of Five Years of Monitoring of Drainage Effects and Impacts.” *Water Resources Development* 17: 633-46.

AQUASTAT. Food and Agriculture Organization of the United Nations, Rome, Italy. Accessed February 28, 2019.

Arab Republic of Egypt (2005). *Water for the Future: National Water Resources Plan, 2017*. Ministry of Water Resources and Irrigation, Planning Sector, Cairo, Egypt.

Bader, Esam. 2004. *Mathematical Programming Models for Optimizing Irrigation Water Management in Egypt*. Ph.D. Thesis, University of Kiel, Germany.

Barnes, Jessica. 2014. *Cultivating the Nile: The Everyday Politics of Water in Egypt.* Durham, North Carolina: Duke University Press.

Brandt, N., P. Schreyer and V. Zipperer. 2017. “Productivity Measurement with Natural Capital.” *Review of Income & Wealth* 63: S7-S21.

CAPMAS(a). (various annual issues). *Statistical Yearbook*. Central Agency for Public Mobilization and Statistics (CAPMAS), Cairo, Egypt.

CAPMAS(b). (various annual issues). *Egypt in Figures.* Central Agency for Public Mobilization and Statistics (CAPMAS), Cairo, Egypt.

Daves, D.W., L.R. Christensen, and W.E. Diewert. 1982. “The Economic Theory of Index Numbers and the Measurement of Input, Output, and Productivity.” *Econometrica* 50(6): 1393-1414.

Central Bank of Egypt. Monthly Statistical Bulletin (various October issues). “Implemented Investments: Agriculture, Irrigation and Reclamation.” Central Bank of Egypt, Cairo.

Conniff, Karen, David Molden, Don Peden, and Seleshi B. Awulachew. 2012. "Nile Water and Agriculture: Past, Present and Future." In, *The Nile River Basin: Water, Agriculture, Governance and Livelihoods* (S.B. Awulachew, V. Smakhtin, D. Molden and D. Peden, eds.) Oxon, UK: Routledge, pp. 30-46.

Dawoud, Seham D.Z. 2014. "Economic Optimal Allocation of Irrigation Water in Egypt." *Journal of Development and Agricultural Economics* 6(12): 472-480.

Dyer, Graham. 1991. "Farm Size-Productivity Reexamined: Evidence from Rural Egypt." *Journal of Peasant Studies* 19: 59-92.

El-Gafy, Inas K., Akram M. El-Ganzori, and Ali I. Mohamed. 2013. "Decision Support System to Maximize Economic Value of Irrigation Water at the Egyptian Governorates Meanwhile Reducing the National Food Gap." *Water Science* 27: 1-18.

Fan, Shenggan, Perrihan Al-Riffai, Moataz El-Said, Bingxin Yu, and Ahmed Kamaly. 2006. "A Multi-level Analysis of Public Spending, Growth and Poverty Reduction in Egypt." DSGD Discussion Paper no. 41. International Food Policy Research Institute, Washington, DC.

FAOSTAT. Food and Agriculture Organization of the United Nations, Rome, Italy. Accessed June 15, 2019.

Fuglie, Keith. 1991. "Vent for Surplus as a Source of Agricultural Growth in Northeast Thailand, 1958 1980." *Journal of Developing Areas* 25: 331 346.

Fuglie, Keith. 2015. "Accounting for Growth in Global Agriculture." *Bio-based and Applied Economics* 4 (3): 221-254.

Fuglie, Keith. 2018. "R&D Capital, R&D Spillovers, and Productivity Growth in World Agriculture." *Applied Economic Perspectives & Policy* 40 (3):421-444.

GAFRD. 2018. *Annual Bulletin of Statistics Fish Production in 2016*. General Authority for Fisheries Resources Development (GAFRD), Ministry of Agriculture and Land Reclamation, Government of Egypt, Cairo.

Giordano, Meredith, Hug Turral, Susanne M. Scheierling, David O. Tréguer, and Peter G. McCornick. 2017. “Beyond ‘More Crop per Drop’: Evolving Thinking on Agricultural Water Productivity. IWMI Research Report 169. International Water Management Institute, Colombo, Sri Lanka.

Gollop, F. and G. Swinand. 2001. “Total Resource Productivity: Accounting for Changing Environmental Quality.” In, New Developments in Productivity Analysis (C. Hulten, E. Dean and M. Harper, eds.). Chicago, IL: University of Chicago Press.

Hazell, Peter B.R., Nicostrato Perez, Gamal Siam, and Ibrahim Soliman. 1995. “Impact of the Structural Adjustment Program on Agricultural Production and Resource Use in Egypt.” EPTD Discussion Paper No. 10, International Food Policy Research Institute, Washington, DC.

Ikram, Khalid. 1980. *Egypt: Economic Management in a Period of Transition*. World Bank Country Report. Baltimore, MD: Johns Hopkins University Press.

Inocencio, Arlene, Masao Kikuchi, Manabu Tonosaki, Atsushi Maruyama, Douglas Merrey, Hilmy Sally and Ijsbrand de Jong (2007). “Costs and Performance of Irrigation Projects: A Comparison of Sub-Saharan Africa and Other Developing Regions.” Research Report 109. International Water Management Institute, Colombo, Sri Lanka.

Kassim, Yumna, Mai Mahmoud, Sikandra Kurdi, and Clemens Breisinger. 2018. *An Agricultural Policy Review of Egypt: First Steps Towards a New Strategy*. International Food Policy Research Institute, Washington, DC.

Larson, Donald F., Rita Butzer, Yair Mundlak, and Al Crego. 2000. "A Cross-country Database for Sector Investment and Capital." *World Bank Economic Review* 14 (2): 371-91.

Meinen, Gerhard, Piet Verbiest, and Peter-Paul de Wolf. 1998. *Perpetual Inventory Method: Service Lives, Discard Patterns and Depreciation Methods*. Department of National Accounts, Statistics Netherlands.

Moussa, M.Z., and T.T. Jones. 1991. "Efficiency and Farm Size in Egypt: A Unit Output Price Profit Function Approach." Applied Economics 23: 21-29.

Radwan, Samir Mohamed. 1973. *Capital Formation in Egyptian Industry and Agriculture, 1882-1967.* Ph.D. Thesis, School of Oriental and African Studies, University of London.

Rosegrant, Mark W., Ximing Cai, and Sarah A. Cline. 2002. *World Water and Food to 2025*. Washington, DC: International Food Policy Research Institute.

Salem, A.M. and M.A. Saleh. 2010. "National Aquaculture Sector Overview: Egypt." National Aquaculture Sector Overview Fact Sheets, FAO Fisheries and Aquaculture Department [online]. Rome. Updated 16 November 2010.

Scheierling, Susanne, David O. Treguer, and James F. Booker. 2016. "Water Productivity in Agriculture: Looking for Water in the Agricultural Productivity and Efficiency Literature." *Water Economics and Policy* 2 (3): 1-33.

Stads, Gert-Jan. 2015. *Agricultural R&D in West Asia and North Africa: Recent Investment and Capacity Trends.* Agricultural Science and Technology Indicators (ASTI), International Food Policy Research Institute, Washington, DC.

UN COMTRADE. International Trade Statistical Database. United Nations Statistics Division, New York. Accessed, June 2019.

van Achthoven, Ton, Zohra Merabet, Karim S. Shalaby, and Frank van Steenbergen. 2004. "Balancing Productivity and Environmental Pressure in Egypt: Toward an Interdisciplinary and Integrated Approach to Agricultural Drainage." Agriculture and Rural Development Working Paper 13, World Bank, Washington, DC.

World Development Indicators. Online Database. World Bank, Washington, DC. Accessed August 30, 2019.

Yates, David N., and Kenneth M. Stzepek. 1996. "Modeling Economy-wide Climate Change Impacts on Egypt: A Case for an Integrated Approach." *Environmental Modeling & Assessments* 1 (3): 119-135.

Figure 1. Optimal allocation of public goods under budget and resource constraints

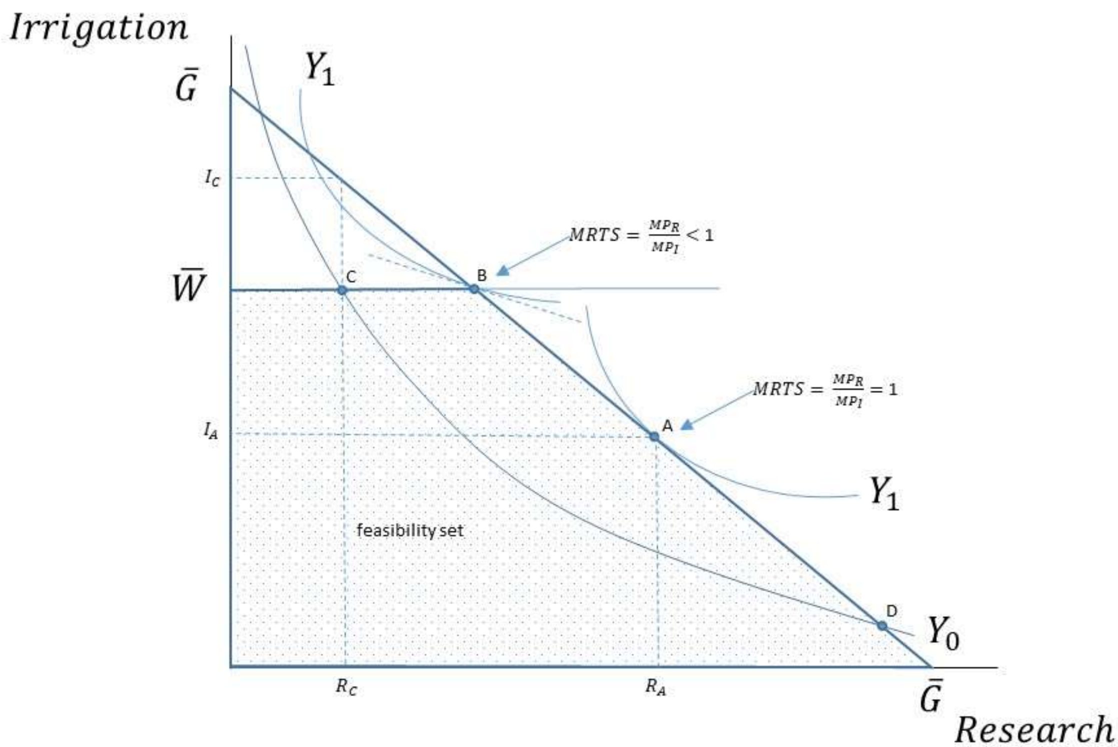

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Figure 2. Production and welfare effects of public supply of irrigation and research

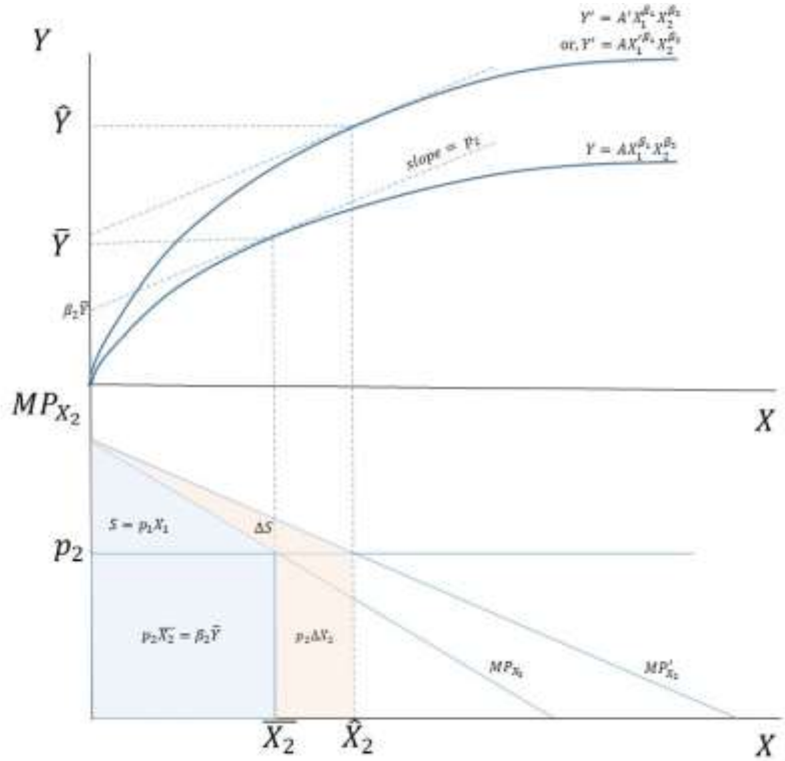
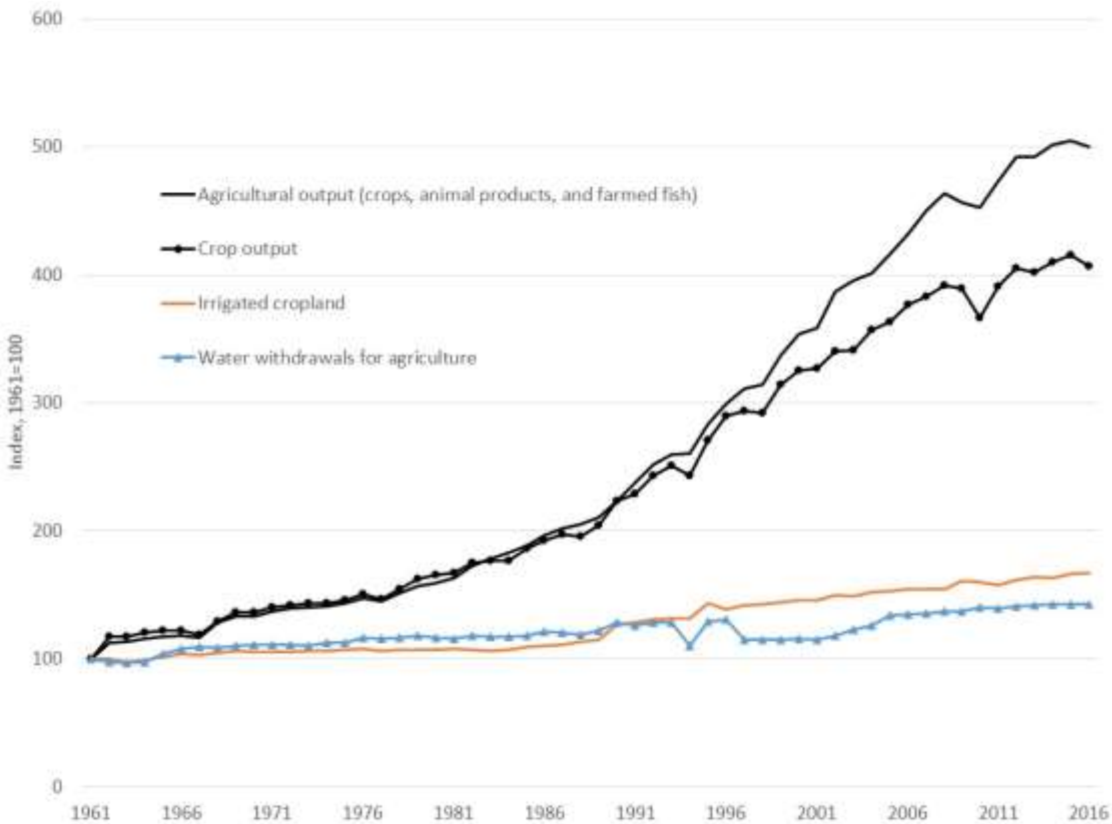


Figure 3: Output, land and water use in Egyptian agriculture



Sources: Land and water quantities are from CAPMAS; Agricultural and crop output indexes are estimated by the authors.

Table 1. Utilization of water and irrigated area for crops

Year	Agricultural water withdrawals	Water applied to fields	Total irrigated cropland	Total crop area harvested	Cereal grains area	Sugar crops area	Fruit & vegetabl e area	Other crops area[1]	Fodder crops area[2]
	million m3	million m3	1000 ha	1000 ha	1000 ha	1000 ha	1000 ha	1000 ha	1000 ha
1961	43,684	NA	2,568	4,165	1,724	47	340	1,094	960
1981	50,680	38,640	2,468	4,730	2,009	109	645	756	1,210
2001	50,210	34,757	3,338	5,697	2,614	191	1,189	623	1,080
2016	62,150	43,659	3,734	6,121	3,226	372	1,610	259	653
% change, 1961-2016	42.3	NA	45.4	47.0	87.2	691.8	373.8	-76.3	-32.0

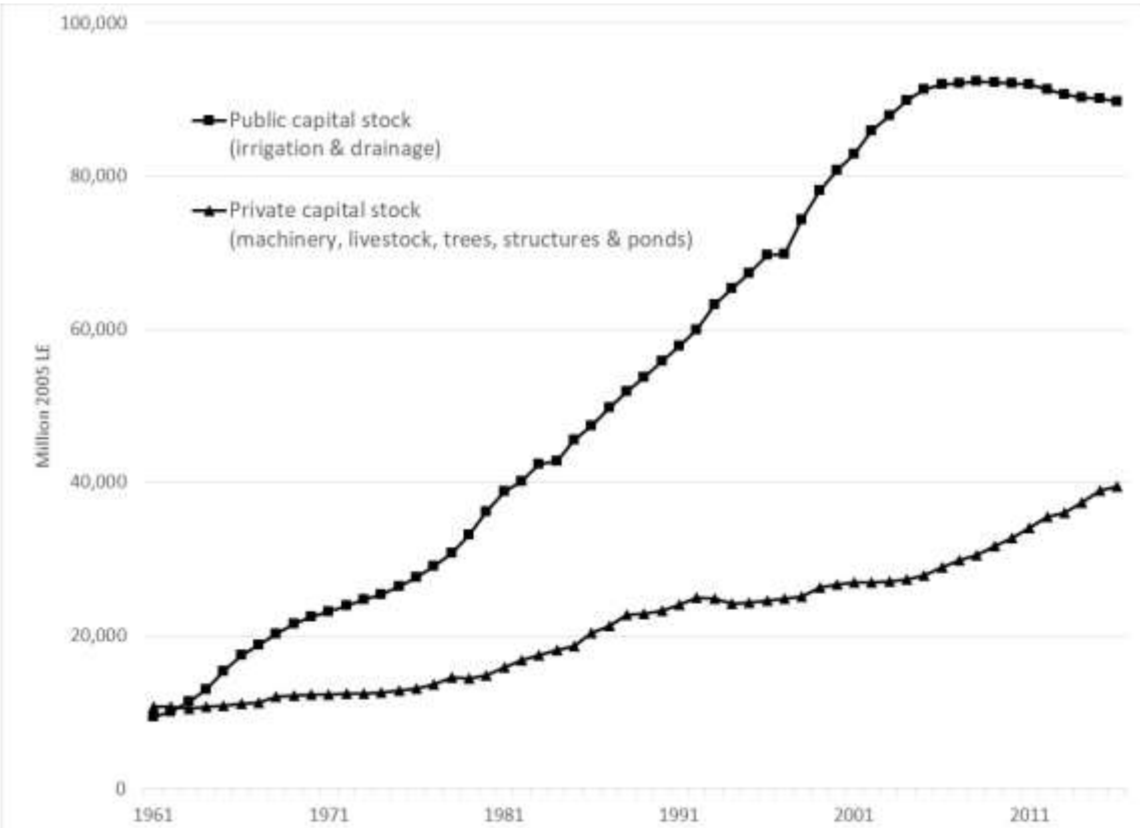
NA=not available.

1 Other field crops include cotton, oilseeds, and grain legumes.

2 Fodder crops consist primarily of Egyptian clover, or *berseem*.

Source: Water data from CAPSAM; area harvested from FAOSTAT, except for fodder crops, which is from CAPSAM.

Figure 4. Value of capital stock in Egyptian agriculture



Source: Authors' estimates.
LE=Egyptian pound.

Table 2. Private and social input cost shares in Egyptian agriculture

Period	Land (residual)	Water	Labor	Capital (private)	Materials	O&M (private)
			Private Inputs			
1961-1970	0.391	0.000	0.114	0.052	0.436	0.008
1971-1980	0.369	0.000	0.168	0.047	0.409	0.007
1981-1990	0.382	0.000	0.128	0.061	0.426	0.004
1991-2000	0.469	0.000	0.088	0.064	0.375	0.003
2001-2010	0.498	0.000	0.086	0.041	0.372	0.002
2011-2016	0.482	0.000	0.117	0.055	0.344	0.003
1961-2016	0.428	0.000	0.117	0.053	0.397	0.005

Period	Land	Water (residual)	Labor	Capital (social)	Materials	O&M (social)
			Social (private and public) Inputs			
1961-1970	0.000	0.321	0.114	0.096	0.436	0.034
1971-1980	0.000	0.286	0.168	0.109	0.409	0.029
1981-1990	0.000	0.272	0.128	0.158	0.426	0.017
1991-2000	0.000	0.340	0.088	0.183	0.375	0.014
2001-2010	0.000	0.408	0.086	0.123	0.372	0.011
2011-2016	0.000	0.392	0.117	0.135	0.344	0.012
1961-2016	0.000	0.332	0.117	0.134	0.397	0.020

Materials include seed, fertilizer, pesticides, feed, and fuels. Social inputs include private inputs plus government spending on irrigation and drainage investment, operation and maintenance (O&M). For private inputs, residual revenues are assigned as rents accruing to irrigated cropland. For social inputs, residual revenues are assigned as rents to agricultural water withdrawals.

Table 3. Tornqvist-Thiel indexes of total agricultural output, input, and productivity

Year	Agricultural output	Agricultural inputs (private)	Agricultural inputs (social)	Agricultural total factor productivity	Crop total factor productivity	Animal-fish total factor productivity	Agricultural total resource productivity
				Index (1961=100)			
1961	100	100	100	100	100	100	100
1962	113	101	100	112	117	101	113
1963	113	101	101	112	116	103	111
1964	116	103	104	112	116	104	112
1965	117	106	109	110	113	104	108
1966	118	107	111	110	113	103	106
1967	116	106	111	109	111	106	105
1968	128	112	117	114	118	107	110
1969	133	115	120	116	120	107	111
1970	133	116	122	115	119	105	109
1971	137	118	124	116	120	109	111
1972	139	121	127	115	119	107	110
1973	141	120	126	117	121	110	112
1974	141	122	129	116	118	110	109
1975	143	127	134	113	115	109	107
1976	147	126	136	116	120	108	108
1977	145	128	138	113	116	109	105
1978	151	131	141	115	120	107	107
1979	157	131	143	119	125	107	109
1980	159	134	147	118	124	106	108
1981	163	138	152	118	123	107	107
1982	172	146	161	118	128	100	107
1983	178	147	164	121	131	103	108
1984	183	153	170	120	131	100	107
1985	189	154	171	123	134	103	110
1986	196	159	178	124	134	105	110
1987	202	159	178	128	137	110	113
1988	205	162	181	126	132	114	113
1989	210	164	184	128	136	113	114
1990	223	174	191	128	141	105	117
1991	237	171	186	139	148	123	128
1992	251	175	191	144	153	127	132
1993	260	176	194	148	158	128	134
1994	260	176	185	148	156	131	141
1995	284	191	204	149	159	131	139
1996	299	191	209	157	171	132	143
1997	311	191	198	163	175	141	157
1998	314	195	203	161	172	140	154
1999	337	200	208	168	184	142	162
2000	354	205	213	173	187	149	166
2001	358	207	215	173	186	151	167
2002	387	209	218	185	193	170	178
2003	396	209	223	189	191	181	178
2004	402	219	234	183	191	168	172
2005	416	218	238	191	196	180	175
2006	432	221	242	195	201	182	179
2007	450	222	243	203	205	194	185
2008	464	226	248	206	206	199	187
2009	457	232	250	197	201	186	182
2010	453	231	253	196	188	200	179
2011	473	233	255	203	198	204	185
2012	492	233	254	211	205	214	194
2013	492	238	258	207	200	210	191
2014	502	241	262	209	204	209	192
2015	505	246	265	205	200	207	191
2016	500	247	266	202	199	201	188
				Trend growth rate (% per year)			
1961-2016	3.16	1.76	1.85	1.40	1.34	1.46	1.31
1961-1986	2.28	1.81	2.28	0.47	0.71	0.03	0.00
1987-2016	3.40	1.51	1.48	1.89	1.48	2.53	1.92

Total factor productivity is the ratio between aggregate agricultural output and private agricultural inputs. Total resource productivity is the ratio of output and social agricultural inputs. Social inputs include private inputs plus the cost of publicly-supplied water for irrigation. The trend growth rate in a variable X is estimated as the β coefficient from the regression of $\ln(X) = \alpha + \beta(\text{Year})$ over the specified years.

Table 4. Sources of growth in crop output

Growth sources	Growth composition	1961-2016	1987-2016	2007-2016	1961-2016	1987-2016	2007-2016
		Trend growth rate (% per year)			Share of growth due to:		
Total crop output	A=B+E	2.41	2.45	1.12	1.00	1.00	1.00
Crop harvested area	B=C+D	0.76	0.90	0.27	0.31	0.37	0.24
Irrigated area	C	1.07	1.23	0.81			
Cropping intensity	D	-0.31	-0.33	-0.54			
Aggregate crop yield	E=F+G+H	1.66	1.55	0.85	0.69	0.63	0.76
Input intensification	F	0.31	0.07	0.97	0.13	0.03	0.87
Cropland reallocation (efficiency change)	G	0.28	0.32	0.42	0.12	0.13	0.37
Net crop yield (technical change)	H	1.06	1.16	-0.54	0.44	0.47	-0.48

Source: Authors' estimates. The trend growth rate in a variable X is estimated as the β coefficient from the regression of ln(X) = α+ β(Year) over the specified years. Total crop TFP growth is the sum of growth due to efficiency and technical changes.

END NOTES

[1] Irrigated cropland includes "Old Areas," or the long-standing irrigated areas of the Nile Valley and Delta, and "New Areas" that have been reclaimed for irrigation since 1952. New Areas include land along the Delta fringes, tidelands along the northern coast, and new irrigation projects in the Sinai and southern Egypt. Between 2001 and 2016, Old Areas declined from 2.69 million hectares (mha) to 2.58 mha, while New Areas increased from 0.65 mha to 1.32 mha (CAPMAS(a)).

[2] The unit resource rent for an environmental service is equivalent to its abatement cost (the foregone income to a producer of reducing one unit of the resource or environmental service in production). An alternative value for environmental services is its social opportunity cost, or the value of the resource or service in its best alternative use. Unit resource rents and social opportunity costs provide conceptually different valuations of environmental sources. Unit resource rents value environmental services from the perspective of current users of the resource. The social opportunity cost provides a measure of the worth of an environmental service from the perspective of society at large. With well-defined property rights over natural assets or optimal environmental regulations, resource rents may be similar to social opportunity costs. In the absence of those conditions, one might expect resource rents to be less than social opportunity costs. Each valuation measure can provide insights into resource use. Estimating and using resource rents to value environmental services from agriculture can reveal important information on how policies affect resource decisions and the welfare of farmers. Using social opportunity costs provides a more complete accounting of the welfare

implications of using resources in agriculture as opposed to other uses, including future consumption (Gollop and Swinand 2001; Brandt, Schreyer and Zipperer 2017).

[3] This is an estimate by the authors using the FAO methodology. The FAOSTAT database actually reports an invalid index of GAO for Egypt, as it omits beef and chicken meat production prior to 1990.

[4] Table 1 provides two measures of water use in agriculture published by CAPMAS(b): *Water withdrawals* are the quantity of water drawn from water sources (rivers, lakes, and aquifers). *Applied water* is the estimated quantity of water applied to fields via on-farm irrigation application systems. A third measure, *crop consumptive use*, is the quantity water taken up by the crop for retention and evapotranspiration. *Water use efficiency* may refer to the ratio consumptive use (plus leaching requirements to prevent the build-up of salts in soils) to applied water or withdrawn water (Giordano et al. 2017). To our knowledge, estimates of crop consumptive use of water in Egypt are not regularly published.

[5] A wide range of assumptions have been made in the literature regarding the service life of irrigation infrastructure. With regular maintenance, dams and lined canals may last hundreds of years although siltation may reduce storage capacity and flow. For example, much of Egypt's irrigation infrastructure dates back to the 19th Century, while the Aswan High Dam and several of the main diversion canals have been operational for more than 50 years. In a review of methods used by OECD governments in estimating capital stock in national accounts, Meinen, Verbiest and de Wolf (1998) found that that assumptions about the service life of buildings and engineering construction ranged from 30 to 80 years. They suggested a "best practice" of 45 years for farm structures and 60 years for government structures. However, Inocencio et al.

(2007) assume an average service life of only 30 years for new irrigation infrastructure in developing countries.

[6] At the official 2005 exchange rate, 5.78 LE equaled 1.00 US$. In constant 2005 US$, between 1961 and 2016 the value of Egyptian agricultural capital stock rose from US$3.9 billion to US$27.4 billion, while the value of gross output increased from US$4.2 billion to US$22.1 billion.

[7] These estimates of water values reported by El Gafy et al. (2013) and Bader (2004) have been converted to 2005 values using the GDP price index for Egypt from World Development Indicators.

[8] The opportunity cost of foregone investment in other productivity-enhancing investments depends, of course, on the marginal product of those investments relative to irrigation. While a formal assessment of this question is beyond the scope of this paper, a back-of-the-envelope calculation in the case of agricultural research is suggestive. Fan et al. (2006) estimated an elasticity for public agricultural R&D in Egypt of 0.25. Assuming values $\beta_1 = 0.4$ for water and η=0.25 for technology in Eq 12 would imply that the marginal value of water would approach zero as the ratio of the stock of capital in irrigation to R&D approaches 1.6. Using our estimates of irrigation capital with Fuglie's (2018) estimates of agricultural R&D capital for Egypt suggests that this ratio might currently be around 20, and that the marginal value of water is thus negative. A negative price for water does *not* imply that producer surplus would rise if water to agriculture was reduced, but it would imply that economic surplus would increase if some public investment was reallocated from irrigation to research.

[9] Not included here is any attribution of TFP to economies of scale. While it is sometimes claimed that the small and fragmented plots that characterize many Egyptian farms are a source of inefficiency (Aboulnaga et al. 2017), studies that have compared productivity across large and small farms have generally found constant or decreasing returns to size (Dyer 1991; Moussa and Jones 1991). Nonetheless, the increase in crop area devoted to high-valued fruit and vegetable crops has been dominated by larger farms (Aboulnaga et al. 2017). Thus, cropland reallocation may also be associated with scale efficiencies in farm size or marketing arrangements.

[10] Studies that have investigated optimal water allocation among crops within Egypt's Nile Valley have found surprising small impacts on output. Using hydrological and linear programming models to account for water movement and seasonality, both Baden (2004) and Dawoud (2014) found that an optimal reallocation of existing water supplies would raise the net returns to crop output by only 3-4 percent (or equivalently, the same output could be produced with 3-4 percent water savings). Both studies concluded that even under optimal crop choice, with present technology a major reduction in water allocation to Egyptian agriculture would likely entail a significant loss in farm output and income.

[11] Egypt has used land taxes to some extent to finance agricultural improvements, for example, to partly cover the cost of installing sub-surface drainage (van Achthoven et al. 2004). However, land holdings under three hectares are excluded from taxes, which covers most farms in Egypt.

Appendix: Data Sources and Constructs

Outputs

Production quantities (metric tons) for all commodities except fodder crops and cultivated fish are from FAOSTAT. Quantities of Egyptian clover (berseem) and fish from aquaculture are from CAPMAS(a). The quantity of crop residues for fodder is estimated from the area planted to grain crops assuming the following dry matter yield: wheat straw: 3.45 T/ha, barley and rye straw: 2.61 T/ha; maize & sorghum leaves: 0.32 T/ha (Von Braun and de Haen 1983). These average yields of crop residues are assumed to be constant over time. A list of all of the commodities included in the aggregate output index and their sub-groupings is given in Table A1.

For crop and non-meat animal products, FAOSTAT (and FAO price archive) provides annual producer prices for 1966-2016. For 1961-1965, producer prices for wheat, rice, cotton, and beef are from Ikram (1980). For other commodities, prices during 1961-65 are assumed to change at same rate as the Egyptian GDP price index (World Development Indicators). For meats, FAOSTAT reports dressed weight prices for 1991-2016 and live weight prices for 1966-2016. Live weight prices for 1966-1990 are adjusted to dressed weight units assuming a constant dressed weight/live weight ratio for each species.

The producer price of forage crops is estimated as a fraction of the average producer price of feed grains (barley, maize, sorghum). In LE/metric ton dry weight, the price of Egyptian clover (berseem) is assumed to be 40%, and the price of crop residues 20%, of the average price of coarse grains. Dry matter content of clover is assumed to be 26%, maize and sorghum leaves 30%, and cereal straw 89% (National Research Council 1982).

The average produce price of cultivated fish is estimated as the total value of production divided by the total quantity produced. Data on quantity and value of fish production since 2004 are from CAPMAS(a). For 1961-2003, these estimates are from FISHSTAT, with value of production in US dollars and converted to Egyptian Pounds at the official market exchange rate (World Development Indicators). Prior to 1991 (when Egypt maintained a fixed exchange rate), the producer price of fish is assumed to grow at same rate as the GDP price index (World Development Indicators).

Inputs

Land and Water

Agricultural land is defined as total area with access to irrigation in hectares. With very little rainfall, virtually all of Egypt's agriculture land is irrigated, with no rainfed cropland or pastures. A second measure of land is harvested area. With year-round access to irrigation water, most of Egyptian's cropland can be continuously cropped. The source of data for agricultural land is CAPMAS(a) and for harvested area is FAO.

Total cubic meters of water withdrawals for agriculture and water applied to fields are from CAPMAS(b).

The implicit producer (private) rental price of irrigated cropland is the residual of gross agricultural revenue after subtracting payments to other private inputs (labor, capital and intermediate inputs).

Similarly, the (social) shadow price of water is estimated as the residual of gross agricultural revenue after subtracting payments to other public and private inputs except land, which is assumed to have zero value in absence of water.

Labor

Labor is the number of permanent workers (family and hired) employed in agriculture, and is from the annual Labor Force Sample Survey (ILOSTAT). Prior to 1991, the annual survey reported very few female workers in agriculture, but since 1991 the survey has had more complete coverage of female labor, which shows that female workers have made up 25-30 percent of the agricultural workforce. We adjust for the earlier undercount by assuming that female workers made up 28.4 percent of the total agricultural workforce (the average for 1991-2017) during 1961-1990. Survey data for male labor for 1976 and 1985-1988 are missing, and we extrapolate for missing years.

Both hired and unpaid family labor is valued at the market wage for hired farm labor. Average monthly earnings for agricultural workers is from the Employment Wages and Hours Worked Survey (ILOSTAT). Monthly earnings are multiplied by 12 to give annual earnings from agricultural work. Earnings data are available for 1970 onward. For earlier years, we assume agricultural wages grew at the same rate as national GDP per capita.

Capital

To account for the heterogeneity of capital, we disaggregate capital into five types and assign different lifespans and depreciation rates to each type. We also break out capital investment by the public and private sectors. We then use the perpetual inventory method (PIM) to derive aggregate private and social capital stocks (where social capital includes both public and private capital). While Egypt's National Accounts data only lists total annual investment in agriculture, the Central Bank of Egypt breaks out public and private "Implemented Investment for Agriculture, Irrigation and Reclamation." We assumed that public investment in agriculture is primarily for irrigation, drainage, and land reclamation (Radwan 1973; Esfahani 1987). For private investment, we construct separate investment series for (i) farm structures and fish ponds, (ii) farm machinery, (iii) fruit-bearing trees, and (iv) inventories of ruminant animal species. We extend the estimates of Radwan (1973) who constructed estimates of agricultural investment for irrigation infrastructure, farm buildings, machinery, and animals over 1882-1967. Thus we have long investment series for each type of public and private capital (except for farm ponds and trees) for deriving estimates of net accumulated capital stock.

Capital stock is estimated as the sum of past capital investment net of depreciation and scrapping. Each type of capital is assigned an average lifespan and depreciation rate. We use the perpetual inventory model (PIM) with a constant geometric pattern of efficiency decay to estimate net capital stock.

Define I_t to be investment in year t in long-lived (capital) inputs, K_t to be the value of accumulated capital stock, and D_t to be the value of the stock that is lost in year t to depreciation and scrapping. Standard nomenclature also refers to I_t as Gross Fixed Capital Formation (GFCF), K_t at Net Fixed Capital Stock (NFCS) and D_t as Capital Consumption (CC). The difference between new investment and depreciation $(I_t - D_t)$ is referred to as Net Fixed Capital Formation (NFCF), which is also equal to $(K_t - K_{t-1})$.

The basic equation of motion for capital stock accumulation is

$$K_t = K_{t-1} + I_t - D_t \qquad \text{Eq A 1}$$

Let δ be the (constant) annual rate of deprecation of capital stock, i.e.,

$$D_t = \delta K_{t-1} \qquad \text{Eq A 2}$$

Substituting this into the equation of motion for capital stock gives:

$$K_t = (1 - \delta)K_{t-1} + I_t \qquad \text{Eq A 3}$$

which, through repeated substitution, can be written as:

$$K_t = \sum_{j=t-L}^{t}(1 - \delta)^{t-j} I_{t-j} \qquad \text{Eq A 4}$$

where L is the lifespan of a capital item (i.e., the age at which it is scrapped).

The value of capital services (i.e., the implicit rental payments for capital) is derived from an equilibrium condition in which it assumed that producers have invested in capital up to the point where the marginal productivity of capital equals its cost. i.e., the present value of future incremental earnings from an additional unit of capital just equals the purchase price of a new capital item. Under this condition, and assuming that real asset prices remain constant over time, then:

$$c = w_K(\delta + r) \qquad \text{Eq A 5}$$

where c is the rental cost of capital that was purchased new at price w_K and r is the discount rate (Jorgenson 1962). From Eq A5 we can see that the service price of capital must compensate for capital depreciation and the opportunity cost of tying up resources in agricultural capital.

Suppose we have several different kinds of capital each with its own depreciation rate and lifespan. Denote these as δ_τ, L_τ for τ types of capital. Then total capital stock at time t is given by the sum of the stock in these individual capital types K_i:

$$K_t = \sum_{i=1}^{\tau} K_{it} = \sum_{i=1}^{\tau} \sum_{j=t-L_i}^{t} \left(1-\delta_j\right)^{t-j} I_{i,t-L_j} \qquad \text{Eq A 6}$$

Each type of capital will have its own rental price $c_i = w_{K_i}(\delta_i + r)$. The total value of capital services in year t, which we denote S_t can then be estimated as:

$$S_t = \sum_{i=1}^{\tau} K_{it}(\delta_i + r). \qquad \text{Eq A 7}$$

There is not much agreement on the appropriate values for the average lifespan and depreciation for capital items, except that buildings and structures have a relatively long useful live with slow depreciation, while machinery and equipment have faster depreciation and shorter lifespans. For example, in a review of methods used by OECD governments in estimating capital stock in national accounts, Meinen, Verbiest and de Wolf (1998) found that that assumptions about the service life of farm buildings ranged from 30 to 80 years, and agricultural machinery from 6 to 20 years. They suggested a "best practice" of 45 years for farm structures, 15 years for agricultural machinery and equipment, and 60 years for government structures. Based on empirical analysis of second-hand capital markets in the United States, Hulten and Wykoff (1996) proposed annual depreciation rates of 3 percent for nonresidential structures and 12 percent for farm machinery. The U.S. Department of Agriculture assumes that farm structures last an average of 38 years and farm machinery 15 years, with annual depreciation increasing as capital ages (USDA(a)).

For this study, we assume services lives for different types of capital equipment and that capital will be scrapped and replaced once it depreciations to 30 percent of its productivity when new. [1] Recall that:

$$K_L = (1-\delta)^L K_0 \qquad \text{Eq A 8}$$

[1] This is an alternative to the "declining balance" (DB) formula described by Hulten and Wykoff (1996) where = DB/L , for some assumed valued of DB, say 2 for durable assets and 1 for non-residential structures.

Defining $\Delta \equiv K_L/K_0$, this can be written as:

$$\delta = 1 - \Delta^{1/L} \qquad \text{Eq A 9}$$

With assumptions on the value of L and assuming Δ=30 percent, Eq A 9 provides a corresponding rate of annual deprecation δ. The exception is livestock capital, where we assume animals[2] have a productive life of 5 years with constant productivity (no depreciation in marginal product) over this period. Table A2 lists our assumptions about service lives and depreciation rates for each type of capital that we use to derive estimates of aggregate capital stock for Egyptian agriculture.

For fruit- and nut-bearing trees, purchase prices are unavailable, so we adopt the approach suggested by Larson et al (2000) to estimate capital stock from area planted and average revenue per hectare for tree crops. We assume that the value of tree capital is equal to the present value of the accumulated farm profit from tree production, where profit is assumed to be 10 percent of the gross value of annual harvest. Trees are assumed to have a productivity life of 20 years, and trees currently in the field are assumed to have an average age of 10 years. Yield depreciates each year at a constant rate until the tree is cut down and replaced. Letting $A_{tree,t}$ be the total area in trees and $\bar{R}_{tree}$ be the average gross revenue from tree harvest, the value of capital stock in trees in year t, $K_{tree,t}$ is then:

$$K_{tree,t} = A_{tree,t} \sum_{i=1}^{10} \left(\frac{1-\delta}{1+r}\right)^i (0.1 * \bar{R}_{tree}) \qquad \text{Eq A 10}$$

where δ is the depreciation rate in yield and r is the producer's discount rate on future earnings.

Technical change that raises the quality (and productivity) of agricultural capital will be reflected in its price. For our purposes we want inputs to be measured in constant quality units so that the productivity gains from adoption of improved technology is measured in TFP. So for the purposes of measuring capital stock in animals and trees, we fix their capital prices at 1960 levels, adjusting them only for the rate of inflation over time. For tree capital, average revenue per hectare over 1960-69 is

[2] We include only long-lived animals as capital, which includes cattle, buffalo, camels, equines, sheep and goats, which are used to produce meat, milk, wool, transport, cultivation and manure services.

used to estimate $\bar{R}_{tree}$ in Eq A10. For animal inventories, the 1960 live animal prices reported in Radwan (1973) are used to value livestock capital.

For farm machinery, we assume that most farm machinery is imported and impute annual investment from the value of tractors, harvesting equipment, seeders, plows, and milking machines imported each year plus 30 percent to account for any domestic manufacture and markup. We use UN COMTRADE as the source of import data from 1965 onward, and for prior years the valued reported by Radwan (1973).

For the value of farm buildings we extended Radwan's (1973) method by assuming that each farm household possesses an average of 50 LE in storage and animal sheds (1960 prices). The number of farm households are from national agricultural census years and extrapolated for intercensus years. We add to this the value of capital in fish ponds, using estimates in Soliman and Yacout (2016) where each ton of fish produced requires LE 938 in capital for pond construction and related equipment (2005 prices). These costs are assumed to change at the same rate as the GDP price index.

The model described above requires interest or discount rates for valuing capital services and stock. The discount rate reflects the opportunity cost of capital, which may be lower for public investment than private investment. To reflect differences in the price of public and private capital, for public capital we use the deposit interest rate for Egypt, and for private capital the lending interest rate, both from World Development Indicators. Over 1961-2016, the nominal deposit interest rate averaged about 5 percent above the rate of inflation in the GDP price index, while the nominal lending rate averaged about 10 percent above this rate of price inflation.

Intermediate Inputs

Intermediate inputs include (i) crop seed, hatching eggs, and fish fingerlings, (ii) fertilizer and manure, (iii) pesticides, (iv) animal feed and fodder, (v) fuel and lubricants, and (vi) irrigation system operation and maintenance (O&M). These are private costs except for irrigation O&M, which are partly paid by the government.

(i) Crop seed, hatching eggs and fish fry

The quantity of crop seed and hatching eggs (metric tons) are from FAOSTAT. The quantity of fish fry (millions of pieces) produced by public and private fish hatcheries is from GAFDA. Expenditures on crop seed and hatching eggs is from CAPMAS(a), and the implied average price is total expenditure/total quantity. For fish fry, Soliman and Yacout (2016) estimate costs are 2.86 percent of revenue from a typical fish pond, and we use this rate to derive expenditures on fry.

(ii) Fertilizer and manure

Data on metric tons of NPK nutrients applied as synthetic fertilizers are from the International Fertilizer Association, and manure applied to fields is from FAOSTAT. Expenditures on these items is from CAPMAS(a), and the implied farm price is the ratio of expenditure to quantity applied.

(iii) Animal feed and fodder

Animal feed consists of feed concentrates and roughage, measured in metric tons of dry weight. Feed concentrates consist of cereal grains, oilseeds and meals, molasses, fish and meat meal, skim milk and whey, used for animal feed. Data on feed utilization is from FAOSTAT commodity balance sheets, except that for 1990 onward, estimates of feed from cereal grains, oilseeds, and their by-products are from USDA(b).

Feed roughage consists of Egyptian clover (berseem) and crop residues. Clover production is from CAPMAS(a). The quantity of crop residues used for feed is estimated from the area planted to cereal crops times the yield of crop residues. We use the following estimates of crop residue yields from Von Braun and de Haen (1983): wheat straw: 3.45 T/ha, barley and rye straw: 2.61 T/ha; maize and sorghum leaves: 0.32 T/ha. We assume that crop residue yields have remained constant over time.

Expenditures on feed concentrates are from CAPMAS(a). For roughages, we assume they are used on or near the farm in which they are grown and that expenditures equals revenues for these products. The price of clover is assumed to be 40 percent, and crop residues 20 percent, the average price of coarse grains, in LE per ton, dry weight. (see section on Outputs, above).

(iv) Pesticides

The total quantity of pesticides (insecticides, fungicides, herbicides, and others), measured in tons of activity ingredients (a.i.), since 1990 is from FAOSTAT. For previous years, we use total imports of pesticide products measured in US dollars, deflated by the USDA(c) index of prices paid for agricultural chemicals to get an index of the quantity imported. We use the growth rate in this index to back cast estimates of the quantity of a.i. applied during 1961-1989. Pesticide expenditure is from CAPMAS(a).

(v) Fuel, oil and lubricants

Expenditures for fuel, oil and lubricants are from CAPMAS(a). Quantities are unavailable, so we represent quantity by the index of machinery capital stock.

(vi) Operation & maintenance (of the irrigation system)

The state is responsible for irrigation O&M up to the delivery point to the *mesqa*, after which the WAU takes responsibility. Perry (1996) estimates that average annual O&M costs for Egypt's irrigation system amount to US$52 per irrigated hectare of cropland, or, on a water volume basis, US$3.44/1000 m^3. Farmer's pay the equivalent of US$12/ha (or US$0.79/1000 m^3 by volume) for their share of system O&M. We assume the total and private cost per m^3 have stayed constant in real terms since 1961 and multiply this by the volume of total water withdrawals for agriculture to derive the total cost of O&M.

Tables A3 through A5 contain annual indexes of output quantities and prices for Egyptian agricultural and sub-groups of commodities. Tables A6 through A9 present input quantities, expenditures and value of capital stock. Table A10 reports Tornqvist-Thiel indexes of output prices.

Appendix References

AQUASTAT. FAO Global Information System on Water and Agriculture. Food and Agriculture Organization of the United Nations, Rome, Italy. Accessed February 28, 2019.

CAPMAS(a). Various annual issues. *Statistical Yearbook*. Central Agency for Public Mobilization and Statistics, Arab Republic of Egypt, Cairo.

CAPMAS(b). Various annual issues. *Egypt in Figures*. Central Agency for Public Mobilization and Statistics, Arab Republic of Egypt, Cairo.

CAPMAS(c). Various annual issues. *Annual Bulletin of Statistics Fish Production*. Central Agency for Public Mobilization and Statistics, Arab Republic of Egypt, Cairo.

Central Bank of Egypt. Various October issues. *Monthly Statistical Bulletin*. Central Bank of Egypt, Cairo.

FAOSTAT. FAO Global Database on Food and Agriculture. Food and Agriculture Organization of the United Nations, Rome, Italy. Accessed June 15, 2019.

FISHSTAT. FAO Fishery Statistical Collection: Global Aquaculture Production. Food and Agriculture Organization of the United Nations, Rome, Italy. Accessed August 30, 2019.

GAFRD (various issues). *Annual Fisheries Statistics*. General Authority for Fisheries Resources Development (GAFRD), Ministry of Agriculture and Land Reclamation, Cairo.

Hulten, Charles R. and Frank C. Wykoff. 1996. "Issues in the Measurement of Economic Depreciation: Introductory Remarks." *Economic Inquiry* 34(1): 10-23.

ILOSTAT. ILO global database of labor statistics. International Labor Organization, Geneva. Accessed August 1 2019.

IFASTAT. IFA global database of fertilizer statistics. International Fertilizer Association, Washington, DC. Accessed February 1 2019

Ikram, Khalid. 1980. *Egypt: Economic Management in a Period of Transition*. World Bank Country Report. Baltimore, MD: Johns Hopkins University Press.

Jorgenson, D.W. 1962. "Capital Theory and Investment Behavior." *American Economic Review* 53 (2): 247-59.

Larson, Donald F., Rita Butzer, Yair Mundlak, and Al Crego. 2000. "A Cross-country Database for Sector Investment and Capital." *World Bank Economic Review* 14 (2): 371-91.

Meinen, Gerhard, Piet Verbiest, and Peter-Paul de Wolf. 1998. *Perpetual Inventory Method: Service Lives, Discard Patterns and Depreciation Methods*. Department of National Accounts, Statistics Netherlands.

National Research Council. 1982. *United States-Canadian Tables of Feed Composition: Nutritional Data for United States and Canadian Feeds, Third Revision*. Washington, DC: National Academy Press.

Perry, C.J. 1996. “Alternative Approaches to Cost Sharing for Water Service to Agriculture in Egypt.” Research Report 2, International Irrigation Management Institute, Colombo, Sri Lanka.

Radwan, Samir Mohamed. 1973. *Capital Formation in Egyptian Industry and Agriculture, 1882-1967.* Ph.D. Thesis, School of Oriental and African Studies, University of London.

Soliman, Naglaa F., and Dalia Yacout. 2016. “Aquaculture in Egypt: Status, Constraints and Potentials.” *Aquaculture International* DOI 10.1007/s10499-016-9989-9. Published online March 11 2016.

UN COMTRADE. International Trade Statistical Database. United Nations Statistics Division, New York. Accessed, June 2019.

USDA(a). Online Data Product: Agricultural Productivity in the U.S., Economic Research Service, U.S. Department of Agriculture, Washington, DC. Accessed November 15 2019.

USDA(b). PS&D Online Database, Foreign Agricultural Service, U.S. Department of Agriculture, Washington, DC. Accessed August 1 2019.

USDA(c). Quick Stat, National Agricultural Statistical Service, U.S. Department of Agriculture, Washington, DC. Accessed January 15 2019.

Von Braun, Joachim and Hartwig de Haen. 1983. “The Effects of Food Price and Subsidy Policies on Egyptian Agriculture.” Research Report 42. International Food Policy Research Institute, Washington, DC.

World Development Indicators. World Bank, Washington, DC. Accessed August 30, 2019.

Table A1. Composition of Agricultural Output

Cereal grains	Other field & forage crops	Tree crops	Vegetables, melons & berries	Meat	Other animal products	Aquaculture
Wheat	Sugar cane	Olives	Potato	Cattle meat	Cow milk	Cultivated fish
Rice	Sugar beet	Walnuts	Sweet potato	Buffalo meat	Buffalo milk	
Barley	Beans, dry	Bananas	Cabbage	Camel meat	Sheep milk	
Maize	Broad beans	Oranges	Artichokes	Sheep meat	Goat milk	
Sorghum/rye	Chickpeas	Tangerines	Lettuce	Goat meat	Poultry eggs	
	Cowpeas	Lemons/limes	Spinach	Pig meat	Wool	
	Lentils	Apples	Tomatoes	Chicken meat	Honey/beeswax	
	Groundnuts	Pears	Pumpkins	Duck meat	Silk cocoons	
	Cotton	Apricots	Cucumbers	Turkey meat		
	Linseed	Peaches	Eggplants	Geese meat		
	Other oilseeds	Plums	Chilies	Other bird meat		
	Other pulses	Grapes	Onions	Rabbit meat		
	Other root crops	Figs	Garlic	Other meat		
	Other pulses	Mangoes	Watermelon			
	Other fiber crops	Dates	Cantelop			
	Egyptian clover (berseem)	Other tree fruits	Strawberries			
	Other roughage		Green beans			
			Green peas			
			Carrots			
			Cauliflower			
			Spice crops			
			Other veg. crops			

Table A2. Assumptions about the Lifespan and Depreciation of Agricultural Capital

Capital type	Useful life (years)	Depreciation (% per year)
Irrigation infrastructure	60	2.0
Farm structures	40	3.0
Fish ponds	20	5.8
Fruit & nut-bearing trees	20	5.8
Farm machinery	15	7.7
Farm animals (ruminants)	5	0.0

Table A3. Tornqvist-Thiel Output Quantity and Price Indexes for Egyptian Agriculture (1961=100)

	All Agriculture		Crops			Animal products			Aquaculture		
Year	Quantity	Price	Quantity	Price	Revenue share	Quantity	Price	Revenue share	Quantity	Price	Revenue share
1961	100	100	100	100	0.709	100	100	0.289	100	100	0.003
1962	113	102	117	102	0.735	102	102	0.263	100	100	0.002
1963	113	103	118	103	0.733	103	104	0.265	115	101	0.003
1964	116	106	121	106	0.735	104	107	0.262	135	102	0.003
1965	117	111	122	110	0.732	106	113	0.265	119	108	0.003
1966	118	115	122	114	0.727	108	117	0.270	113	111	0.003
1967	116	122	119	123	0.724	112	121	0.274	108	114	0.002
1968	128	115	130	114	0.708	126	117	0.290	108	116	0.002
1969	133	114	137	114	0.722	126	115	0.275	113	117	0.002
1970	133	123	137	121	0.711	127	129	0.287	115	131	0.003
1971	137	123	140	122	0.717	131	126	0.280	135	133	0.003
1972	139	128	142	127	0.713	133	133	0.284	154	138	0.003
1973	141	145	144	144	0.720	134	146	0.276	173	148	0.004
1974	141	171	143	171	0.717	136	173	0.280	173	162	0.003
1975	143	184	146	185	0.722	138	183	0.275	173	177	0.003
1976	147	212	150	213	0.726	139	209	0.270	212	198	0.004
1977	145	255	146	250	0.701	141	271	0.295	250	222	0.004
1978	151	287	154	277	0.698	144	314	0.297	288	244	0.005
1979	157	333	162	328	0.717	145	351	0.278	327	301	0.005
1980	159	404	165	396	0.716	145	431	0.278	365	338	0.005
1981	163	455	167	442	0.703	153	496	0.291	404	331	0.005
1982	172	562	175	515	0.660	166	706	0.334	462	413	0.006
1983	178	661	177	586	0.626	178	886	0.369	481	465	0.005
1984	183	714	177	626	0.605	191	977	0.390	519	503	0.006
1985	189	860	186	765	0.621	191	1,154	0.371	805	562	0.008
1986	196	982	192	876	0.622	200	1,308	0.370	875	634	0.008
1987	202	1,079	197	964	0.620	207	1,432	0.372	892	713	0.008
1988	205	1,211	196	1,108	0.621	218	1,545	0.369	1,004	809	0.009
1989	210	1,444	204	1,409	0.667	216	1,655	0.322	1,163	963	0.011
1990	223	1,596	224	1,576	0.693	216	1,778	0.297	1,191	1,134	0.011
1991	237	1,776	229	1,788	0.681	252	1,876	0.307	1,185	1,536	0.012
1992	251	1,896	243	1,931	0.692	264	1,956	0.297	1,229	1,570	0.012
1993	260	1,990	251	1,975	0.672	277	2,182	0.319	1,040	1,631	0.009
1994	260	2,137	243	2,098	0.644	297	2,400	0.346	1,089	1,741	0.010
1995	284	2,352	271	2,340	0.666	309	2,590	0.325	1,381	1,531	0.009
1996	299	2,468	290	2,462	0.676	315	2,696	0.312	1,753	1,759	0.012
1997	311	2,542	294	2,545	0.662	347	2,741	0.326	1,648	2,046	0.012
1998	314	2,615	292	2,560	0.638	352	2,944	0.341	2,681	2,239	0.021
1999	337	2,630	314	2,592	0.643	366	2,959	0.330	4,351	1,888	0.027
2000	354	2,664	325	2,556	0.618	379	3,087	0.335	6,540	2,342	0.047
2001	358	2,732	327	2,618	0.613	389	3,160	0.339	6,594	2,469	0.048
2002	387	2,830	340	2,715	0.593	448	3,331	0.366	7,236	2,206	0.042
2003	396	3,168	341	3,090	0.590	467	3,664	0.366	8,561	2,275	0.044
2004	402	3,707	357	3,582	0.602	448	4,405	0.356	9,068	2,417	0.042
2005	416	4,001	363	3,824	0.585	473	4,873	0.370	10,380	2,473	0.044
2006	432	4,341	377	4,149	0.584	489	5,281	0.369	11,443	2,697	0.047
2007	450	4,982	383	5,037	0.602	527	5,562	0.351	12,221	3,023	0.047
2008	464	5,574	392	5,690	0.602	546	6,262	0.355	13,343	2,851	0.042
2009	457	5,614	389	5,453	0.578	526	6,822	0.376	13,567	3,003	0.046
2010	453	6,428	366	6,505	0.571	546	7,415	0.374	17,684	3,127	0.055
2011	473	7,241	391	7,510	0.596	549	8,062	0.349	18,977	3,475	0.055
2012	492	7,575	406	7,930	0.599	575	8,305	0.346	19,572	3,621	0.055
2013	492	8,033	402	8,205	0.580	577	9,207	0.362	21,107	3,798	0.058
2014	502	8,185	410	8,157	0.566	586	9,611	0.369	21,867	4,232	0.065
2015	505	8,879	415	8,808	0.568	580	10,604	0.370	22,593	4,338	0.063
2016	500	9,763	407	9,265	0.538	567	12,183	0.380	26,359	5,328	0.083

Table A4. Tornqvist-Thiel Output Quantity and Price Indexes for Egyptian Crop Agriculture (1961=100)

	Cereal grains			Other field and fodder crops			Tree crops (fruits & nuts)			Vegetables, melons & berries		
Year	Quantity	Price	Revenue share	Quantity	Price	Revenue share	Quantity	Price	Revenue share	Quantity	Price	Revenue share
1961	100	100	0.198	100	100	0.366	100	100	0.054	100	100	0.091
1962	126	102	0.215	118	100	0.383	106	100	0.049	106	100	0.087
1963	124	104	0.210	115	101	0.376	110	101	0.051	118	101	0.095
1964	124	108	0.200	123	102	0.396	100	102	0.045	120	102	0.094
1965	121	111	0.200	125	110	0.387	108	108	0.048	126	108	0.097
1966	129	115	0.223	118	120	0.351	113	111	0.050	131	111	0.103
1967	133	126	0.248	112	138	0.334	111	114	0.048	120	115	0.094
1968	147	113	0.236	121	123	0.319	106	117	0.048	141	114	0.105
1969	141	117	0.227	136	128	0.352	126	106	0.054	146	100	0.089
1970	148	122	0.227	134	132	0.340	115	120	0.050	144	116	0.093
1971	150	122	0.217	136	127	0.343	131	126	0.056	148	123	0.102
1972	149	127	0.211	139	132	0.351	144	128	0.059	151	123	0.092
1973	154	142	0.221	136	152	0.334	146	154	0.064	159	147	0.102
1974	155	170	0.220	129	179	0.326	160	178	0.066	168	171	0.105
1975	164	182	0.226	125	190	0.318	165	196	0.070	181	187	0.108
1976	165	198	0.201	128	197	0.320	168	264	0.071	196	267	0.134
1977	151	230	0.182	130	231	0.316	158	315	0.072	195	311	0.131
1978	167	252	0.193	135	261	0.296	172	360	0.081	196	341	0.128
1979	164	292	0.165	142	274	0.319	192	446	0.088	217	433	0.144
1980	167	367	0.200	145	421	0.297	187	500	0.088	228	455	0.131
1981	169	395	0.163	145	389	0.308	196	601	0.103	230	516	0.130
1982	175	474	0.160	147	483	0.282	242	662	0.104	232	572	0.114
1983	179	551	0.164	143	589	0.256	263	728	0.103	235	623	0.103
1984	176	587	0.151	146	612	0.257	247	783	0.098	244	649	0.099
1985	178	749	0.160	153	804	0.269	251	883	0.087	277	753	0.105
1986	182	846	0.162	151	944	0.246	281	1,039	0.090	303	926	0.124
1987	196	911	0.157	142	963	0.247	311	1,187	0.092	324	1,109	0.124
1988	204	1,061	0.171	141	1,156	0.231	312	1,337	0.084	302	1,309	0.135
1989	237	1,450	0.227	141	1,751	0.243	362	1,515	0.092	283	1,452	0.105
1990	280	1,619	0.241	145	1,857	0.248	404	1,698	0.091	293	1,709	0.113
1991	298	1,750	0.229	148	1,955	0.241	406	2,126	0.104	283	1,991	0.106
1992	313	1,910	0.224	150	2,052	0.239	502	2,253	0.119	297	2,062	0.109
1993	321	1,992	0.222	164	2,161	0.257	490	2,226	0.113	298	1,904	0.079
1994	322	2,064	0.224	147	2,333	0.224	511	2,484	0.114	290	2,294	0.083
1995	346	2,333	0.215	149	2,492	0.248	601	2,707	0.117	385	2,553	0.085
1996	355	2,481	0.217	164	2,716	0.240	637	2,801	0.124	424	2,481	0.094
1997	388	2,515	0.228	161	2,798	0.215	632	2,986	0.122	405	2,567	0.097
1998	382	2,492	0.221	158	2,871	0.197	645	3,075	0.126	412	2,585	0.094
1999	416	2,542	0.228	164	2,934	0.188	708	3,078	0.130	444	2,559	0.097
2000	431	2,455	0.208	165	2,756	0.178	733	3,132	0.133	476	2,544	0.100
2001	400	2,508	0.188	181	2,787	0.194	786	3,221	0.141	457	2,563	0.090
2002	435	2,623	0.192	178	2,942	0.179	830	3,303	0.136	469	2,620	0.085
2003	446	3,031	0.206	168	3,547	0.160	807	3,681	0.123	510	3,239	0.101
2004	450	3,905	0.221	181	4,529	0.183	869	3,696	0.116	536	3,105	0.082
2005	484	4,161	0.225	161	4,778	0.163	907	3,959	0.121	572	3,169	0.078
2006	487	4,300	0.204	163	4,862	0.155	1,032	4,638	0.125	586	4,267	0.100
2007	468	5,409	0.209	175	6,182	0.174	1,030	5,375	0.124	628	4,830	0.095
2008	520	6,777	0.260	155	8,437	0.145	1,036	5,265	0.096	675	5,346	0.102
2009	506	6,185	0.208	147	7,035	0.155	1,035	5,477	0.112	726	5,115	0.104
2010	434	7,539	0.192	159	8,584	0.169	998	6,346	0.105	676	6,173	0.104
2011	495	8,304	0.212	167	9,877	0.164	1,032	7,830	0.101	683	8,391	0.119
2012	534	9,222	0.227	155	10,728	0.159	1,121	7,715	0.102	719	8,102	0.112
2013	545	9,527	0.223	157	10,991	0.160	1,132	8,002	0.098	660	8,568	0.099
2014	526	9,586	0.214	159	11,333	0.150	1,238	7,807	0.103	700	8,220	0.099
2015	526	10,336	0.209	155	12,058	0.153	1,363	8,449	0.108	704	9,114	0.098
2016	529	10,613	0.189	150	11,876	0.142	1,354	9,188	0.112	659	10,023	0.094

Table A5. Tornqvist-Thiel Output Quantity and Price Indexes for Egyptian Animal Agriculture (1961=100)

	Meat			Milk			Eggs, wool, honey & silk		
Year	Quantity	Price	Revenue share	Quantity	Price	Revenue share	Quantity	Price	Revenue share
1961	100	100	0.189	100	100	0.085	100	100	0.014
1962	102	103	0.173	103	100	0.077	107	100	0.013
1963	104	106	0.179	97	101	0.071	87	101	0.014
1964	106	109	0.178	98	102	0.069	87	102	0.015
1965	108	115	0.181	100	108	0.070	89	108	0.014
1966	110	120	0.184	101	111	0.070	136	111	0.016
1967	113	125	0.187	102	114	0.070	167	114	0.017
1968	122	127	0.198	134	98	0.076	212	98	0.016
1969	122	123	0.185	137	99	0.076	227	100	0.014
1970	121	134	0.187	139	118	0.084	227	118	0.016
1971	124	134	0.187	143	109	0.077	265	108	0.015
1972	126	147	0.195	146	108	0.074	265	107	0.015
1973	126	161	0.189	149	117	0.072	265	116	0.015
1974	128	188	0.187	152	145	0.076	265	143	0.016
1975	128	196	0.180	155	158	0.078	265	157	0.018
1976	129	216	0.169	158	177	0.075	303	280	0.026
1977	130	246	0.164	161	315	0.104	303	336	0.027
1978	132	265	0.154	163	379	0.108	303	500	0.035
1979	133	302	0.147	165	431	0.104	303	473	0.027
1980	135	376	0.151	167	521	0.103	303	583	0.024
1981	142	398	0.146	170	648	0.112	303	797	0.033
1982	159	532	0.165	170	1,013	0.130	326	1,065	0.040
1983	178	718	0.199	173	1,130	0.121	379	1,411	0.048
1984	195	812	0.219	178	1,252	0.124	417	1,366	0.046
1985	192	960	0.205	184	1,493	0.123	454	1,593	0.042
1986	198	1,149	0.212	186	1,610	0.114	492	1,593	0.044
1987	208	1,261	0.216	188	1,757	0.111	530	1,730	0.044
1988	219	1,362	0.215	191	1,949	0.110	568	1,730	0.044
1989	220	1,482	0.193	194	2,019	0.095	606	1,821	0.034
1990	220	1,548	0.172	199	2,351	0.097	341	1,821	0.028
1991	280	1,605	0.189	209	2,549	0.093	665	1,863	0.024
1992	297	1,690	0.187	220	2,599	0.089	711	1,933	0.021
1993	307	1,973	0.206	235	2,679	0.090	761	2,005	0.022
1994	340	2,208	0.234	232	2,752	0.085	475	2,530	0.027
1995	356	2,380	0.221	235	2,877	0.075	501	3,057	0.029
1996	354	2,509	0.209	263	2,920	0.077	486	3,093	0.026
1997	383	2,568	0.216	310	2,922	0.084	525	3,129	0.025
1998	393	2,644	0.220	307	3,534	0.096	549	3,166	0.025
1999	411	2,651	0.213	326	3,542	0.095	568	3,275	0.022
2000	423	2,704	0.211	332	3,900	0.100	568	3,357	0.025
2001	427	2,776	0.211	347	3,962	0.102	568	3,437	0.027
2002	499	2,956	0.232	365	4,134	0.100	572	3,460	0.034
2003	483	3,313	0.220	466	4,482	0.118	572	3,483	0.029
2004	484	4,078	0.227	416	5,199	0.103	572	4,091	0.025
2005	504	4,526	0.234	464	5,631	0.110	572	4,835	0.026
2006	522	4,830	0.230	478	5,788	0.104	572	7,320	0.034
2007	551	4,952	0.210	526	6,630	0.109	572	7,088	0.032
2008	560	5,574	0.208	531	7,460	0.108	572	7,958	0.039
2009	571	6,151	0.235	503	8,275	0.114	606	7,597	0.028
2010	589	6,861	0.238	515	8,627	0.107	689	7,815	0.029
2011	591	7,172	0.213	515	10,442	0.110	700	7,844	0.026
2012	597	7,624	0.210	519	10,064	0.098	757	8,170	0.037
2013	614	8,659	0.230	495	10,782	0.095	632	8,720	0.037
2014	623	9,208	0.238	506	10,746	0.093	635	9,121	0.038
2015	637	10,611	0.256	466	11,774	0.086	461	7,526	0.028
2016	628	12,427	0.269	453	12,342	0.080	471	9,621	0.030

Table A6. Private Agricultural Input Expenditures

	Total Expenditure	Land		Labor		Capital		Intermediate Inputs	
		Quantity	Expenditure	Quantity	Expenditure	Stock	Services	Quantity	Expenditure
Year	Million LE	1000 ha	Million LE	1000 workers	Million LE	Million LE	Million LE	Index	Million LE
1961	649.3	2,290.7	251.5	4,869.3	72.1	100.0	38.6	100.0	281.5
1962	746.0	2,290.7	333.4	4,912.6	73.8	99.0	38.3	101.8	294.9
1963	759.0	2,244.1	292.3	4,968.0	81.0	97.1	37.9	104.8	342.1
1964	799.6	2,263.0	300.8	5,073.5	90.7	99.7	39.3	107.5	363.1
1965	844.4	2,330.6	303.4	5,244.2	101.0	100.1	41.6	111.4	391.9
1966	879.6	2,389.0	327.3	5,227.2	105.9	102.5	43.8	111.1	395.8
1967	924.3	2,361.7	360.0	5,264.8	107.7	104.6	45.9	109.8	403.5
1968	953.5	2,398.2	388.9	5,362.9	107.1	111.0	49.6	121.1	400.5
1969	987.0	2,429.7	392.1	5,475.7	113.3	111.6	50.3	125.8	423.9
1970	1,065.9	2,417.5	410.9	5,557.8	133.4	112.4	57.0	128.5	456.1
1971	1,092.4	2,413.7	407.7	6,033.8	144.8	112.0	57.5	129.5	473.9
1972	1,161.3	2,424.2	368.1	6,253.0	225.1	112.3	59.7	135.0	499.6
1973	1,318.5	2,429.7	479.0	5,987.8	215.6	112.3	64.1	134.6	550.4
1974	1,565.5	2,428.0	554.5	5,719.7	274.5	113.1	70.6	143.2	655.4
1975	1,708.6	2,455.3	681.1	6,033.8	217.2	115.9	79.3	151.6	719.5
1976	2,017.8	2,467.1	869.1	5,853.0	280.9	119.6	72.1	151.6	782.3
1977	2,389.1	2,434.3	936.4	5,672.2	408.4	127.1	93.7	158.6	935.7
1978	2,806.5	2,452.0	1,111.1	5,422.3	390.4	139.3	126.7	168.7	1,162.0
1979	3,384.0	2,446.9	1,163.5	5,525.7	729.4	138.9	179.9	169.6	1,290.7
1980	4,166.2	2,444.4	1,357.4	5,704.4	908.9	143.1	228.3	176.0	1,649.0
1981	4,796.3	2,467.9	1,593.8	5,483.8	894.8	156.1	269.9	188.8	2,015.6
1982	6,276.3	2,445.2	1,953.6	5,412.6	1,180.5	166.7	359.6	213.2	2,754.7
1983	7,635.9	2,434.7	2,521.0	5,471.2	1,444.4	173.4	421.4	216.6	3,217.6
1984	8,467.7	2,458.3	2,961.6	5,341.4	1,318.9	181.4	477.3	236.0	3,675.8
1985	10,527.8	2,508.7	4,430.4	5,315.7	1,227.6	187.2	549.5	235.1	4,282.0
1986	12,477.9	2,528.0	5,496.1	5,290.2	1,142.7	205.9	682.4	248.3	5,112.4
1987	14,109.8	2,546.5	5,202.3	5,264.8	1,326.7	216.5	867.2	245.1	6,664.0
1988	16,063.3	2,596.9	6,714.9	5,239.5	1,320.4	230.2	1,082.4	252.1	6,890.3
1989	19,626.4	2,633.4	8,714.6	5,214.3	1,501.7	232.2	1,388.8	255.3	7,953.6
1990	23,024.2	2,905.6	9,282.7	5,599.0	2,284.4	234.1	1,700.8	262.6	9,672.3
1991	27,187.4	2,949.7	12,318.2	4,333.0	2,027.8	240.4	2,091.0	257.3	10,654.8
1992	30,698.3	2,996.3	13,392.6	5,535.0	2,723.2	248.9	2,639.6	253.6	11,827.4
1993	33,355.3	3,015.2	14,427.7	5,189.0	3,175.7	245.9	2,572.6	262.1	13,054.1
1994	35,867.9	3,012.7	16,259.9	5,361.0	3,473.9	239.5	2,479.2	262.3	13,538.8
1995	43,006.0	3,281.5	20,902.9	5,216.0	3,692.9	239.7	2,758.0	291.9	15,500.2
1996	47,627.2	3,176.5	22,431.1	5,369.3	4,316.9	241.4	2,833.0	302.4	17,881.7
1997	50,929.2	3,244.9	25,388.3	4,951.0	3,921.2	242.5	2,806.8	301.8	18,653.9
1998	52,995.9	3,259.6	26,154.3	4,823.0	4,745.8	245.6	2,767.9	319.9	19,165.1
1999	57,266.8	3,296.2	28,367.9	4,807.0	5,133.9	255.6	2,897.7	335.6	20,702.9
2000	60,791.0	3,337.3	28,752.1	5,097.0	5,443.6	259.2	3,108.3	344.7	23,315.0
2001	63,144.3	3,337.1	31,342.6	5,010.0	4,388.8	259.0	3,180.5	353.8	24,058.4
2002	70,597.4	3,422.2	36,939.0	4,913.0	6,249.3	258.0	3,378.4	353.1	23,846.1
2003	80,872.3	3,407.6	43,286.2	5,412.0	6,039.8	256.7	3,530.0	348.5	27,811.4
2004	95,976.1	3,477.0	48,130.0	5,958.0	7,588.7	258.6	3,930.1	377.3	36,092.4
2005	107,402.7	3,506.5	53,968.3	5,972.0	9,889.6	263.9	4,193.8	365.4	39,085.9
2006	120,874.1	3,532.6	63,896.4	6,371.0	10,856.2	274.6	4,510.5	371.8	41,324.0
2007	144,349.3	3,537.7	73,868.1	6,886.0	12,064.3	284.3	5,226.7	364.3	52,865.4
2008	166,282.7	3,541.5	67,396.1	7,116.0	14,725.5	297.9	6,060.6	375.0	77,731.8
2009	164,894.9	3,688.9	76,070.4	6,876.0	16,254.0	317.2	6,998.2	383.9	65,162.4
2010	187,140.6	3,671.3	95,431.1	6,728.0	18,051.0	335.0	7,592.0	384.3	65,605.4
2011	220,011.8	3,620.2	112,982.1	6,810.0	20,327.7	350.5	8,885.6	395.9	77,304.9
2012	239,462.5	3,695.8	121,794.4	6,378.0	22,744.5	365.9	11,867.0	388.9	82,439.5
2013	254,130.5	3,760.8	130,979.7	6,703.0	25,958.5	374.8	13,476.1	398.4	83,038.6
2014	263,778.5	3,744.9	130,533.6	6,694.0	29,017.4	391.5	15,066.9	409.8	88,404.0
2015	287,949.4	3,820.2	137,364.2	6,397.0	31,122.0	410.9	17,289.5	426.6	101,341.9
2016	314,445.0	3,822.5	119,782.8	6,478.0	60,945.0	417.3	21,187.2	430.2	111,649.0

LE = Egyptian pounds (nominal values)

Table A7 Private Expenditures on Intermediate Inputs

Year	Total Million LE	Fertilizer & manure Million LE	Feed & fodder Million LE	Seed Million LE	Pesticide Million LE	Energy Million LE
1961	281.5	51.1	39.1	32.2	2.8	2.6
1962	294.9	54.6	41.5	34.1	3.9	2.6
1963	342.1	81.6	43.2	36.3	6.1	2.4
1964	363.1	94.6	42.2	36.0	6.4	2.5
1965	391.9	105.8	51.2	36.5	6.6	2.4
1966	395.8	89.9	53.4	35.5	16.4	2.7
1967	403.5	86.4	57.9	45.6	5.5	2.8
1968	400.5	98.3	53.4	42.5	3.9	2.9
1969	423.9	106.0	57.9	43.3	7.0	2.8
1970	456.1	115.1	62.1	42.4	7.7	2.7
1971	473.9	120.9	59.6	46.0	8.8	2.8
1972	499.6	132.7	65.8	46.2	12.3	2.5
1973	550.4	126.0	75.5	51.4	17.1	2.4
1974	655.4	148.1	108.6	60.1	29.2	2.5
1975	719.5	165.1	124.0	67.1	36.7	3.4
1976	782.3	178.5	156.5	87.9	15.8	4.4
1977	935.7	190.9	189.4	123.6	27.3	7.1
1978	1,162.0	265.0	259.9	133.6	47.3	12.1
1979	1,290.7	317.3	279.9	159.6	45.4	13.7
1980	1,649.0	393.8	426.6	196.8	35.6	18.6
1981	2,015.6	460.9	535.9	216.7	57.9	28.4
1982	2,754.7	556.6	890.7	242.4	73.7	32.3
1983	3,217.6	572.6	1,102.6	274.8	54.0	43.9
1984	3,675.8	603.6	1,398.1	295.4	78.4	53.9
1985	4,282.0	671.4	1,556.4	367.8	61.8	62.3
1986	5,112.4	841.5	1,954.4	405.1	105.1	82.5
1987	6,664.0	1,831.7	1,965.7	457.2	143.6	100.0
1988	6,890.3	1,514.3	2,263.1	505.2	292.1	120.9
1989	7,953.6	1,459.2	2,794.1	670.8	311.0	135.8
1990	9,672.3	2,242.1	3,409.4	779.2	113.9	155.2
1991	10,654.8	2,696.0	3,382.2	898.3	122.2	174.3
1992	11,827.4	2,979.8	3,603.5	956.5	149.7	189.2
1993	13,054.1	3,371.9	4,000.0	1,031.2	160.2	204.1
1994	13,538.8	2,842.8	4,767.6	1,119.1	130.3	212.8
1995	15,500.2	3,791.7	4,949.7	1,494.2	176.7	222.5
1996	17,881.7	4,707.7	6,041.8	1,565.1	248.5	234.8
1997	18,653.9	4,607.3	6,569.2	1,544.7	304.3	222.3
1998	19,165.1	4,072.5	7,586.4	1,596.8	163.3	229.7
1999	20,702.9	4,351.6	8,675.2	1,472.2	125.6	234.8
2000	23,315.0	5,505.5	9,601.6	1,393.9	134.8	224.0
2001	24,058.4	5,385.9	10,228.3	1,456.0	106.5	200.8
2002	23,846.1	4,967.2	10,079.9	1,629.5	105.3	181.9
2003	27,811.4	6,806.8	10,877.4	1,898.3	127.1	160.1
2004	36,092.4	8,902.3	14,095.1	2,272.5	141.5	153.8
2005	39,085.9	10,845.2	14,734.2	2,466.4	113.5	168.2
2006	41,324.0	11,457.2	15,064.5	2,338.2	201.3	192.3
2007	52,865.4	14,120.2	18,127.8	2,936.1	185.8	212.8
2008	77,731.8	30,520.4	21,875.7	4,399.8	349.0	327.3
2009	65,162.4	18,793.9	21,708.2	4,067.1	533.8	518.6
2010	65,605.4	13,305.1	24,459.4	3,772.0	890.0	137.4
2011	77,304.9	14,209.6	34,098.0	4,138.3	838.0	529.1
2012	82,439.5	13,648.0	35,215.8	4,606.0	839.0	1,842.0
2013	83,038.6	12,868.0	35,730.6	4,715.0	882.0	2,709.0
2014	88,404.0	14,502.0	39,116.7	5,017.0	862.0	2,893.0
2015	101,341.9	13,030.0	48,872.6	5,244.0	1,194.0	3,074.0
2016	111,649.0	14,879.0	53,038.3	5,531.0	1,291.0	4,052.0

LE = Egyptian pounds (nominal values)

Table A8. Private Agricultural Capital Stock, Investment, and Expenditures on Capital Services

	Total Private Capital			Structures	Machinery	Animals	Fruit trees
	Stock	Investment	Services	Stock	Stock	Stock	Stock
Year	Million LE	Million LE	Million LE	Million LE	Million LE	Million LE	Million LE
1961	318.5	59.7	38.6	95.1	30.8	165.3	27.3
1962	316.4	50.1	38.3	95.7	30.3	161.3	29.1
1963	313.9	48.9	37.9	96.9	28.1	158.7	30.2
1964	325.0	63.9	39.3	98.0	30.1	163.1	33.8
1965	345.8	63.2	41.6	103.7	29.9	175.1	37.1
1966	363.8	71.6	43.8	106.9	32.5	183.2	41.3
1967	382.0	73.5	45.9	110.2	34.4	191.7	45.6
1968	416.1	106.1	49.6	112.5	35.1	218.8	49.7
1969	423.5	85.3	50.3	113.8	33.4	225.1	51.2
1970	481.8	98.5	57.0	128.4	35.5	257.7	60.3
1971	488.0	96.4	57.5	130.5	32.9	263.2	61.4
1972	508.6	106.4	59.7	135.3	31.0	276.4	65.9
1973	547.7	113.3	64.1	145.7	30.8	299.6	71.6
1974	604.4	129.8	70.6	159.9	32.8	330.3	81.4
1975	675.3	151.9	79.3	175.9	43.9	365.1	90.3
1976	772.7	178.3	72.1	196.8	57.3	408.3	110.4
1977	903.3	215.1	93.7	221.7	94.5	460.0	127.1
1978	1,056.4	269.5	126.7	243.6	156.0	514.3	142.3
1979	1,295.9	253.8	179.9	301.8	199.4	621.7	172.9
1980	1,492.8	331.0	228.3	340.3	246.9	699.4	206.2
1981	1,563.9	399.0	269.9	338.1	327.4	694.1	204.3
1982	2,068.0	501.2	359.6	428.3	474.3	894.8	270.6
1983	2,412.4	530.3	421.4	490.4	582.8	1,012.2	327.1
1984	2,721.2	619.8	477.3	539.1	687.6	1,127.6	366.8
1985	3,120.6	642.6	549.5	611.0	818.7	1,261.4	429.5
1986	3,845.8	943.5	682.4	700.5	1,097.4	1,437.2	610.7
1987	4,537.8	995.5	867.2	800.2	1,325.1	1,699.1	713.4
1988	5,473.0	1,287.8	1,082.4	921.8	1,615.3	2,097.9	837.9
1989	6,592.3	1,235.7	1,388.8	1,115.5	1,905.8	2,546.5	1,024.6
1990	7,868.7	1,528.8	1,700.8	1,335.4	2,152.0	3,184.9	1,196.5
1991	9,453.7	2,003.0	2,091.0	1,603.8	2,383.3	4,050.5	1,416.0
1992	11,696.4	2,490.6	2,639.6	1,949.1	2,636.8	4,962.8	2,147.8
1993	12,605.4	2,310.6	2,572.6	2,168.9	2,605.9	5,467.4	2,363.2
1994	13,304.1	2,286.8	2,479.2	2,417.1	2,718.5	5,825.1	2,343.5
1995	14,871.3	3,017.0	2,758.0	2,769.0	2,919.8	6,494.1	2,688.4
1996	16,122.8	3,427.6	2,833.0	3,053.1	2,961.5	7,144.1	2,964.1
1997	17,888.5	3,737.8	2,806.8	3,452.5	3,050.4	8,033.1	3,352.5
1998	18,532.6	3,900.4	2,767.9	3,662.5	3,162.1	8,236.9	3,471.1
1999	19,603.8	4,452.9	2,897.7	3,845.1	3,078.7	8,641.9	4,038.1
2000	20,744.7	4,425.5	3,108.3	4,178.9	3,057.7	9,308.6	4,199.5
2001	21,279.4	3,918.3	3,180.5	4,327.6	2,807.8	9,773.6	4,370.5
2002	21,989.7	3,717.3	3,378.4	4,561.5	2,623.0	10,551.8	4,253.3
2003	23,519.5	3,835.5	3,530.0	5,002.1	2,443.9	11,485.6	4,588.0
2004	26,538.3	4,392.7	3,930.1	5,684.5	2,598.0	13,050.0	5,205.8
2005	28,779.0	4,961.0	4,193.8	6,228.9	2,749.7	14,126.3	5,674.0
2006	32,220.9	5,815.3	4,510.5	6,802.5	3,016.5	15,355.0	7,046.9
2007	37,445.3	6,717.5	5,226.7	7,849.6	3,758.4	17,771.8	8,065.6
2008	42,762.1	7,331.1	6,060.6	8,985.6	6,485.6	19,038.5	8,252.3
2009	49,258.4	8,957.5	6,998.2	10,154.8	10,014.4	19,751.6	9,337.8
2010	56,164.3	10,122.0	7,592.0	11,563.2	13,383.3	20,573.4	10,644.4
2011	65,176.7	11,883.0	8,885.6	13,125.0	16,426.6	23,446.3	12,178.8
2012	80,994.8	14,341.1	11,867.0	15,925.9	21,131.3	28,893.3	15,044.4
2013	89,522.7	13,839.1	13,476.1	17,592.3	24,649.0	30,282.5	16,998.9
2014	103,339.4	17,346.9	15,066.9	20,360.3	29,760.5	33,850.3	19,368.4
2015	118,401.9	18,984.8	17,289.5	22,888.5	35,875.7	37,152.6	22,485.1
2016	127,505.8	18,096.6	21,187.2	25,272.1	38,845.8	39,013.9	24,374.0

LE = Egyptian pounds (nominal values)

Table A9.Water Inputs, Irrigation Capital and Expenditures for Irrigation Operation & Maintenance (O&M)

	Total Public Capital in Irrigation			Public O&M	Private O&M	Water Inputs	
	Stock	Investment	Services	Expenditures	Expenditures	Withdrawals	Applied to fields
Year	Million LE	Million LE	Million LE	Million LE	Million LE	Million m3	Million m3
1961	272.5	20.5	20.3	25.0	5.8	43,684	NA
1962	295.0	29.8	22.0	24.4	5.6	42,612	NA
1963	334.7	45.4	25.0	24.5	5.7	42,357	NA
1964	387.7	57.9	28.9	24.9	5.7	42,629	26,990
1965	481.3	82.3	35.9	28.0	6.5	45,453	30,050
1966	564.1	82.0	42.1	29.9	6.9	47,290	32,000
1967	621.6	56.2	46.4	31.0	7.2	47,647	29,170
1968	684.6	67.6	51.1	31.5	7.3	47,500	34,945
1969	734.9	61.3	54.9	32.2	7.4	48,300	36,082
1970	861.2	53.3	64.3	36.5	8.4	48,600	36,677
1971	897.7	43.9	67.0	36.8	8.5	48,350	36,959
1972	958.5	50.3	71.6	38.0	8.8	48,335	36,738
1973	1,064.5	57.6	79.5	40.8	9.4	48,270	36,184
1974	1,194.3	54.2	89.2	45.5	10.5	49,200	37,462
1975	1,367.0	84.1	102.1	49.8	11.5	49,130	37,565
1976	1,593.0	99.4	79.7	57.8	13.3	51,077	38,931
1977	1,882.1	129.0	125.5	64.4	14.9	50,710	38,640
1978	2,179.1	159.4	171.6	70.8	16.3	50,850	38,740
1979	2,854.6	218.0	256.9	88.7	20.5	51,620	39,142
1980	3,511.6	368.1	362.9	98.1	22.6	50,770	38,695
1981	3,687.9	323.7	442.5	95.8	22.1	50,680	38,640
1982	4,772.6	265.8	620.4	121.4	28.0	51,500	39,263
1983	5,676.7	406.4	738.0	136.6	31.5	51,400	39,191
1984	6,198.4	178.7	805.8	147.5	34.0	51,300	39,142
1985	7,384.8	610.2	960.0	165.6	38.2	51,600	39,660
1986	8,669.0	504.2	1,127.0	192.2	44.4	53,060	40,445
1987	10,249.0	701.8	1,332.4	214.9	49.6	52,740	40,225
1988	12,107.5	728.7	1,574.0	239.7	55.3	51,870	39,598
1989	14,961.3	854.4	2,044.7	293.4	67.7	53,300	40,736
1990	18,307.9	1,084.8	2,563.1	363.6	83.9	56,100	42,720
1991	22,004.0	1,223.3	3,080.6	414.1	95.6	55,020	46,647
1992	27,009.7	1,573.4	3,781.4	500.4	115.5	56,170	49,514
1993	30,947.5	2,325.1	4,332.7	542.8	125.3	56,200	49,247
1994	34,656.8	1,863.4	4,794.2	502.9	116.0	48,007	34,896
1995	39,796.1	2,072.4	5,140.3	659.1	152.1	56,479	48,066
1996	44,131.6	2,467.2	5,534.8	712.4	164.4	56,998	36,624
1997	48,624.4	1,223.3	5,754.9	688.7	158.9	50,150	34,857
1998	53,015.7	4,351.3	6,023.9	705.6	162.8	50,190	34,948
1999	56,202.8	3,895.1	6,304.6	712.7	164.5	50,230	34,493
2000	60,411.5	3,212.5	6,921.1	745.4	172.0	50,540	34,680
2001	63,174.3	2,888.3	7,238.7	754.4	174.1	50,210	34,757
2002	67,546.4	3,695.5	7,655.3	799.5	184.5	51,580	35,373
2003	73,882.1	3,220.3	7,554.4	888.0	204.9	53,656	36,551
2004	84,390.5	3,559.0	8,207.0	1,018.3	235.0	55,100	37,855
2005	90,990.1	3,170.1	8,393.8	1,148.3	265.0	58,500	29,775
2006	98,472.7	2,799.7	7,894.2	1,243.4	286.9	59,000	40,948
2007	111,016.9	2,433.7	8,992.4	1,407.1	324.7	59,300	42,075
2008	124,868.6	2,849.5	10,717.9	1,597.5	368.6	60,000	42,846
2009	138,739.7	2,743.3	11,781.3	1,776.2	409.9	60,000	34,561
2010	152,512.4	2,878.1	12,556.9	1,998.0	461.1	61,300	37,794
2011	170,100.3	3,275.7	14,869.6	2,216.5	511.5	60,900	30,867
2012	201,726.6	2,672.7	19,449.8	2,674.5	617.2	61,500	32,109
2013	217,666.6	2,950.4	21,077.4	2,935.8	677.5	62,100	37,817
2014	241,132.0	4,146.1	21,500.9	3,279.2	756.7	62,350	38,257
2015	264,622.8	5,213.0	23,573.5	3,604.9	831.9	62,350	36,750
2016	280,234.9	5,039.2	27,626.5	3,817.7	881.0	62,150	43,659

LE = Egyptian pounds (nominal values)

NA= not available.

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