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# AGRICULTURAL R&D INVESTMENT, POVERTY, AND ECONOMIC GROWTH IN SUB-SAHARAN AFRICA

## Prospects and Needs to 2050

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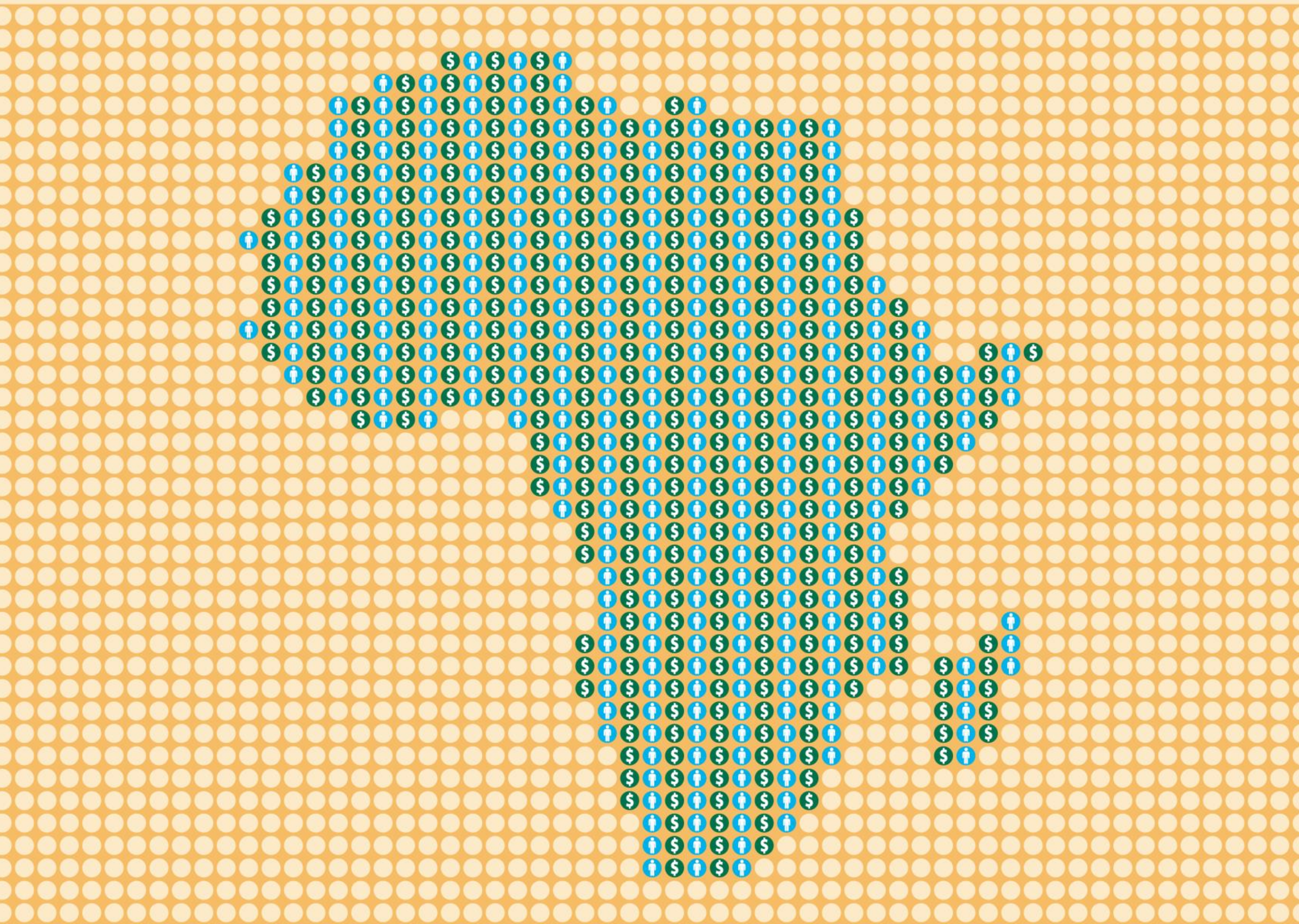
AGRICULTURAL R&D: INVESTING IN AFRICA'S FUTURE
Analyzing Trends, Challenges, and Opportunities



## Table of Contents



## List of Tables



## List of Figures

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## Acronyms and Abbreviations

| | |
|---|---|
| CGIAR | Consultative Group on International Agricultural Research |
| DRC | Democratic Republic of China |
| II | invention–innovation |
| PPP | purchasing power parity |
| R&D | research and development |
| SSA | Sub-Saharan Africa |

## Abstract

This paper looks at past trends in the allocation of funding to agricultural research and development (R&D) in developing countries, as well as the future performance of agriculture-related projects in these regions based on past investment, and the optimal allocation of R&D investment across regions to maximize global welfare. The analysis is based on a dynamic linear programming model of global agriculture. Results suggest that present allocations of agricultural R&D in Sub-Saharan Africa (SSA) are highly inefficient. Substantial gains could be made by increasing investment in East Africa in the next 20 years. At the global level, optimal allocation of R&D investment among developing countries shows that maximizing welfare for these countries requires the allocation of a significant portion of total investment to some of SSA's large agricultural producers.

## 1. INTRODUCTION

Stagnation in world food production and declining yield growth rates in primary food crops threaten world food security. Among the many factors leading to these concerns, a major force is the long-run stagnation or even decline in public research in many poor countries and within the Consultative Group on International Agricultural Research (CGIAR). In the 1990s, total agricultural research and development (R&D) spending in developing countries increased from $3.3 billion (1992) to $3.9 billion (2000), or by 2.1 percent per year. This spending was largely driven by Asia, where yearly spending increased by 3.5 percent. In Africa, agricultural R&D expenditure grew at a slower rate of 1.9 percent per year, also showing large variability across countries (ASTI 2010). Data for recent years show little improvement in Sub-Saharan Africa (SSA) with an average growth rate of 2 percent for the period 2000–08 and a wide variation between countries (standard deviation of 6).

Given the importance of public agricultural R&D investment to sustain long-run productivity growth in developing countries, this study analyzes future implications of past R&D investment in SSA and patterns of investment allocation that could improve performance of the agricultural sector in the coming decades. More specifically, the study focuses on the following questions: What are the growth consequences of past low agricultural R&D investment for SSA in terms of agricultural growth and food availability? If development agencies were to double present investment in agricultural R&D in SSA, how should this investment be allocated to maximize regional welfare?

The analysis is based on a linear dynamic global multiregional model of agricultural production that includes 41 countries and regions in Africa, Asia, Latin America, as well as high-income countries. Output growth in the agricultural/food sector depends on agricultural productivity, which is a function of agricultural R&D investment. Exports and imports take place between countries, and the global market and the model includes an equation relating the poverty headcount to agricultural and market equilibrium equations for each country. The model is used to simulate how much investment is required and how it can be optimally allocated across developing regions and within SSA.

The model is dynamic and nonrecursive, and it is solved to maximize the optimal growth path to the year 2050, simulating different scenarios. The first scenario focuses on the future growth implications of SSA's R&D investment of the past 15 years. This scenario is the reference or baseline scenario and shows economic growth and poverty if SSA countries maintain present levels of R&D investment. A second scenario compares the impact of doubling R&D investment of all SSA countries against the first scenario, looking at the optimal allocation of R&D between African regions. The final scenario analyzes optimal allocation of R&D investment among all developing regions. The amount of R&D going into each country is defined endogenously by the model with total available R&D being the exogenous variable. Data are from FAOSTAT (FAO 2011), World Development Indicators (World Bank 2011b), POVCALNET (World Bank 2011a), and ASTI (2010–11). Key parameters of the model (agricultural GDP, R&D elasticities, and poverty–GDP elasticities) are estimated for countries and regions in SSA.

## 2. METHODOLOGY

The model used to analyze the impact of agricultural R&D investment in developing countries combines the advantage of being simple, with particularly useful features for the analysis of optimal allocation of investment. These models have been extensively used since the early years of development economics for both macro- and microeconomic analysis.[1] One of the main virtues of this approach is its flexibility, as it allows the specification of inequality constraints to reflect particular features of an economy. Moreover, the many possible variations of this type of model can be represented by a core structure that includes an objective function, constraints, and nonnegativity conditions.

[1] The main concepts in this section are extracted from Dervis, de Melo, and Robinson (1982), Chapters 2 to 4.

The particular model used in this study uses some features of the input-output models discussed in Dervis, DeMelo, and Robinson (1982, Chapter 2) and the model in Chenery and Macewan (1979) in the Harrod–Domar tradition, whereby the behavior of the model is given in three equations (Dervis, DeMelo, and Robinson 1982, 32):

$$C_{i,t+1} \geq (1 + p_i) * C_{i,t}, \quad (1)$$

$$Y_{i,t} \leq yb_i + 1/k_i * K_{i,t,} \text{ and} \quad (2)$$

$$M_{i,t} + Y_{i,t} \geq C_{i,t} + E_{i,t}. \quad (3)$$

Equation (1) states that consumption grows at rate *p* during the planning period. Equation (2) links output growth to capital stock (*Ks*) and to a fixed coefficient (*k*), the incremental output–capital ratio. Finally, Equation (3) relates supply and demand, establishing that total supply of a good (domestic production plus imports) should be greater or equal than total demand (consumption, investment, and exports). The model is dynamic and nonrecursive; can feature multiple sectors, regions, and T time periods; and is solved to maximize the discounted sum of aggregate consumption over the years (*t)*, and the value of the capital stock left at the end of the planning period.

This general framework has been adapted to the analysis of global agricultural R&D investment in the long run. The key behavioral equation is Equation (2), representing the growth mechanism of the agricultural sector. In the long run, agricultural growth depends on technical change channeled through R&D investment, which is the only factor in the production function. The assumption made here is that R&D is, in the long run, the engine of growth of agricultural production.

In this context, Equation (2) relates agricultural output in region *i* to the stock of R&D in the same region through the coefficient *k*, which is derived from estimated R&D output elasticities for different regions. R&D stock is built by yearly flows of R&D investment, and is defined as the weighted sum of yearly R&D investment in the previous 15 periods, assuming that there is a time lag between investment and its effect on output. $I_{i,t}$ in Equation (4) represents R&D investment in region *i* and year *t*, while the value of weights $\beta$ is defined so as to increase between *t*-1 and *t*-5, contributing with the highest weight between year *t*-6 and *t*-10 and decreasing until the contribution is zero in year *t*-15, following a symmetric pattern.

$$K_{i,t} = \sum_{k=1}^{15}(\beta_{t-k} * I_{i,t-k}). \quad (4)$$

Total yearly investment $I_{i,t}$ has two components (Equation 5). The first component ($s_{i,t}$) is domestic investment, which is assumed  to occur at constant historical growth rates for each region. The second component ($F_{i,t}$) is R&D investment eventually allocated to a particular region from an exogenous source (development aid). This component will be discussed further in the simulations in Section 4.

$$I_{i,t} = s_{i,t} + F_{i,t}. \quad (5)$$

The total amount of available investment to be allocated every year between regions is fixed:

$$WF_t \geq \sum_i F_{i,t}. \quad (6)$$

Exports in the model are assumed to be exogenous, while agricultural imports are endogenous and a function of output growth (Equation 7).

$$M_{i,t} \geq mb_i + my_i * (Y_{i,t} - yb_i), \quad (7)$$

where $mb_i$ are imports by region *i* in the base year, $yb_i$ is agricultural output in the base year, and $my_i$ is a parameter that transforms changes in output into imports. Equation (8) imposes equilibrium in the global market:

$$\sum_i e_{i,t} - \sum_i M_{i,t} = 0. \quad (8)$$

The objective function in the model maximizes the discounted sum of the world's aggregate consumption (all regions) over the $T$ years of the planning period, plus the value of the terminal capital stock. The parameter $\rho$ is the social rate of time preferences and is constant over time

$$Max \sum_{i=1}^{N}\sum_{t=1}^{T}\left(\frac{1}{1+\rho_i}\right)^t C_{i,t} + \sum_{i=1}^{N} V_{i,T+1}K_{i,T+1.} \quad (9)$$

The model links total number of poor people ($P$) at the national level to agricultural production through equation (10):

$$P_{i,t} = P0_{i,t} + mgp_i * \left(Y_{i,t} - Y0_i\right), \quad (10)$$

where $P0_{it}$ is the number of poor people in region $i$ calculated as a fixed percentage of the total population, other things being equal; $mgp_i$ is the marginal effect on poverty with changes in agricultural GDP; and the last term is the change in agricultural GDP between year $t$ and the initial year.

## 3. DATA, PARAMETERS, AND SCENARIOS

The model includes 41 countries and regions (see Appendix Table A1), and data to benchmark the model were obtained from different sources, including FAOSTAT, World Development Indicators, Penn World Tables, and COMTRADE. Data on R&D spending are from ASTI's database and publications (Beintema and Stads 2008, 2011). The model relies on two key parameters: the output elasticity with respect to R&D investment and the poverty elasticity with respect to output. Nin-Pratt and Fan (2010) summarize some of the evidence on the value of these parameters. The highest values for the output–R&D elasticities are found in Asia, and in particular in China, whose values appear to be the most robust estimates from the literature. Only three R&D elasticities were found for Africa in the literature, and they appear to be too low. No elasticity values were found in the literature for Latin America.

Data availability for the poverty–output elasticity is also very limited; fewer papers look at this issue than at internal rate of return (IRR) and output–R&D elasticities. The main reference for the elasticity values is the paper by Thirtle, Lin, and Piesse (2003), which estimates the impact of research-led agricultural productivity growth on poverty reduction in Africa, Asia, and Latin America.

Given the limited information available on the value of these parameters, output–R&D and output–poverty elasticities are estimated for this study with the same data used to benchmark the model and run simulations. Table 1 shows results of output–R&D estimates using panel data with country fixed effects, running separate regressions for the different regions. A similar exercise was conducted to estimate poverty elasticities using panel data and figures on the number of poor and agricultural output per capita of rural population. Asian countries show the highest output—R&D elasticities with an average of 0.18. Output–R&D elasticities in SSA are the lowest, with an average value of 0.05, while the estimated elasticity for Central and South America shows intermediate values (0.11). Asian and Latin American countries show similar values for the poverty elasticities, and they are much larger than those obtained for SSA (Table 2).

**Table 1. Estimated coefficients of production function, including R&D stock as a factor using panel data and fixed effects**

| | Sub-Saharan Africa | | | | | Central and South America | | | | | Asia | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Coefficient | P>t | 95% confidence interval | | | Coefficient | P>t | 95% confidence interval | | | Coefficient | P>t | 95% confidence interval | |
| Land | 1.788 | 0.00 | 1.55 | 2.02 | Land | 0.300 | 0.06 | –0.01 | 0.61 | Land | 1.306 | 0.00 | 0.70 | 1.91 |
| Labor | 0.395 | 0.00 | 0.31 | 0.48 | Labor | 0.096 | 0.34 | –0.11 | 0.30 | Labor | 0.446 | 0.00 | 0.32 | 0.57 |
| Fertilizer | –0.004 | 0.79 | –0.03 | 0.02 | Fertilizer | 0.059 | 0.19 | –0.03 | 0.15 | Fertilizer | 0.024 | 0.27 | –0.02 | 0.07 |
| Animal stock | 0.344 | 0.00 | 0.30 | 0.39 | Animal stock | 0.842 | 0.00 | 0.66 | 1.02 | Animal stock | 0.419 | 0.00 | 0.34 | 0.49 |
| Tractors | 0.093 | 0.00 | 0.05 | 0.13 | Tractors | –0.539 | 0.60 | –2.62 | 1.54 | Tractors | 0.067 | 0.00 | 0.02 | 0.11 |
| **R&D** | **0.049** | **0.00** | **0.02** | **0.08** | **R&D** | **0.111** | **0.04** | **0.01** | **0.22** | **R&D** | **0.182** | **0.00** | **0.12** | **0.25** |
| Ethiopia | –0.792 | 0.00 | –1.07 | –0.52 | Brazil | –0.370 | 0.77 | –2.91 | 2.17 | India | –4.405 | 0.00 | –6.20 | –2.61 |
| Ghana | 2.960 | 0.00 | 2.60 | 3.32 | Chile | –0.456 | 0.78 | –3.74 | 2.83 | Nepal | 0.670 | 0.02 | 0.10 | 1.24 |
| Côte d'Ivoire | 2.623 | 0.00 | 2.37 | 2.87 | Colombia | –1.652 | 0.52 | –6.85 | 3.55 | Pakistan | –1.358 | 0.00 | –2.08 | –0.63 |
| Kenya | 0.910 | 0.00 | 0.62 | 1.20 | Costa Rica | –0.429 | 0.91 | –8.06 | 7.20 | Sri Lanka | 1.807 | 0.00 | 0.94 | 2.68 |
| Madagascar | 0.434 | 0.00 | 0.22 | 0.65 | Guatemala | –1.302 | 0.76 | –9.96 | 7.36 | China | –5.836 | 0.00 | –8.26 | –3.41 |
| Nigeria | 0.327 | 0.01 | 0.08 | 0.58 | | | | | | Indonesia | –2.099 | 0.00 | –3.06 | –1.13 |
| Senegal | 2.837 | 0.00 | 2.40 | 3.28 | | | | | | Malaysia | 0.578 | 0.02 | 0.11 | 1.05 |
| South Africa | –0.313 | 0.03 | –0.59 | –0.03 | | | | | | Philippines | –0.285 | 0.08 | –0.60 | 0.03 |
| Sudan | –1.736 | 0.00 | –1.99 | –1.48 | | | | | | | | | | |
| Constant | –11.809 | 0.00 | –13.91 | –9.71 | Constant | 9.407 | 0.48 | –17.13 | 35.94 | Constant | –5.706 | 0.04 | –11.20 | –0.21 |

Source: Author's estimates based on FAO (2011) and ASTI (2010–11).

**Table 2. Estimated poverty elasticity, agricultural output per capita by rural population, and number of poor people by region**

| Variable | Asia | Latin America | Sub-Saharan Africa |
|---|---|---|---|
| Log agricultural output per capita by rural population | –0.601*** | –0.685* | –0.220* |
| | –0.166 | –0.373 | –0.113 |
| Constant | 8.872*** | 7.035*** | 6.388*** |
| | –0.52 | –1.491 | –0.338 |
| Observations | 133 | 154 | 339 |
| R-squared | 0.103 | 0.069 | 0.029 |
| Number of countries | 15 | 19 | 39 |

Source: Author estimation using data from POVCALNET (2011) and FAO (2011).
Note: Robust standard errors are shown in parentheses; *** p<0.01, ** p<0.05, and * p<0.1.

The model as described above was used to run three different groups of simulation scenarios. The first group focuses on SSA, while a second group of scenarios analyzes R&D allocation at a global level for developing countries. The baseline scenario assumes that research investment will continue to grow at the historical rate in all regions (1994–2008). This baseline scenario is compared with two additional scenarios: a first that doubles total agricultural R&D investment in SSA but still allocates this increased investment across countries, also following the investment patterns for the 1994–2008 period. A second scenario also doubles R&D investment, but this new investment is then optimally allocated among the countries and subregions of SSA for the period 2010–50. The same exercise is repeated at the global level, comparing the baseline scenario with the investment-doubling scenario and the scenario that maximizes global welfare. The third group of scenarios checks the sensibility of results in the second group of scenarios by running the model using two extreme values of R&D elasticity for SSA countries.

## 4. GROWTH AND POVERTY IMPLICATIONS OF R&D INVESTMENT IN THE 1990s AND 2000s

The first scenario explores the implications of SSA's R&D investment of the 2000s for the coming years. Table 3 shows investment levels, investment intensity measured as a share of investment in agricultural GDP, and investment growth rates for major developing countries. Ghana, Kenya, and South Africa are the countries with the highest R&D investment intensity and with the best historical record of agricultural R&D investment and innovation in SSA. Ghana, Nigeria, Tanzania, and Uganda show the largest growth in investment in recent years; however, growth in investment has proved to be highly volatile. Ethiopia significantly increased R&D investment during the 1990s, although, like Tanzania, it started with very low initial levels of investment.

**Table 3. R&D investment per year during the late-2000s, R&D growth rate, and R&D intensity**

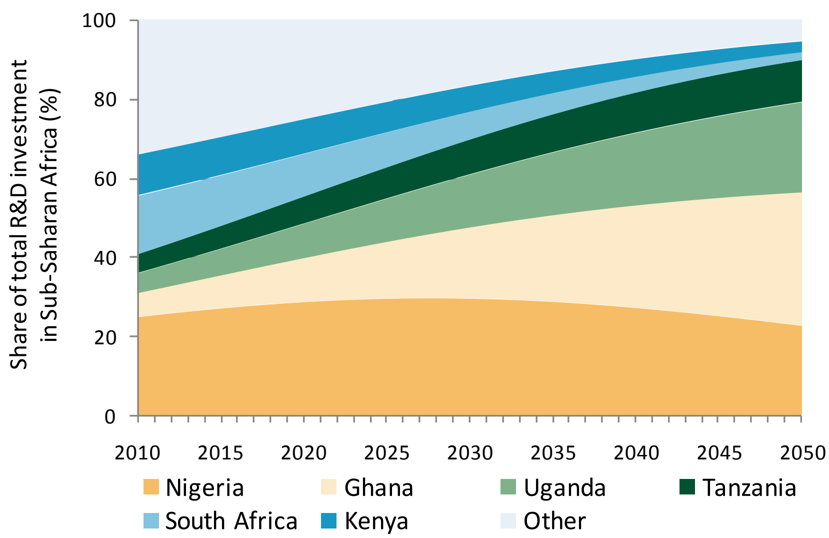
| Country/region | R&D growth rate (%) | R&D (million 2005 PPP dollars) | R&D share (%) | AgGDP (million 2005 PPP dollars) | AgGDP share (%) | R&D/ AgGDP (%) |
|---|---|---|---|---|---|---|
| Nigeria | 5.2 | 404 | 2.8 | 48,825 | 1.7 | 0.8 |
| Ghana | 10.4 | 95 | 0.7 | 8,531 | 0.3 | 1.1 |
| Côte d'Ivoire | – | 46 | 0.3 | 5,782 | 0.2 | 0.8 |
| Cameroon | – | 50 | 0.3 | 6,191 | 0.2 | 0.8 |
| Senegal | –1.8 | 25 | 0.2 | 2,690 | 0.1 | 0.9 |
| Sahel | – | 59 | 0.4 | 14,799 | 0.5 | 0.4 |
| Ethiopia | 0.4 | 69 | 0.5 | 17,972 | 0.6 | 0.4 |
| Sudan | – | 73 | 0.5 | 24,462 | 0.9 | 0.3 |
| Kenya | 2.0 | 172 | 1.2 | 11,048 | 0.4 | 1.6 |
| Uganda | 9.5 | 88 | 0.6 | 9,307 | 0.3 | 0.9 |
| Tanzania | 7.6 | 77 | 0.5 | 16,346 | 0.6 | 0.5 |
| Rest of East Africa | – | 18 | 0.1 | 4,440 | 0.2 | 0.4 |
| South Africa | 0.3 | 272 | 1.9 | 9,916 | 0.3 | 2.7 |
| Madagascar | 4.2 | 12 | 0.1 | 3,803 | 0.1 | 0.3 |
| Rest of West Africa | – | 69 | 0.5 | 8,686 | 0.3 | 0.8 |
| Democratic Republic of Congo | – | 18 | 0.1 | 5,951 | 0.2 | 0.3 |
| Central Africa | – | 16 | 0.1 | 5,361 | 0.2 | 0.3 |
| Southern Africa | – | 49 | 0.3 | 12,242 | 0.4 | 0.4 |
| Sub-Saharan Africa | 3.3 | 1,612 | 11.3 | 216,352 | 7.5 | 0.7 |
| Egypt | – | 104 | 0.7 | 43,478 | 1.5 | 0.2 |
| North Africa | – | 142 | 1.0 | 59,351 | 2.1 | 0.2 |
| Middle East | – | 1,288 | 9.0 | 536,824 | 18.7 | 0.2 |
| Middle East and North Africa | – | 1,535 | 10.8 | 639,652 | 22.3 | 0.2 |
| China | 8.1 | 4,874 | 34.1 | 838,500 | 29.2 | 0.6 |
| Indonesia | 1.2 | 175 | 1.2 | 102,557 | 3.6 | 0.2 |
| Thailand | – | 265 | 1.9 | 45,669 | 1.6 | 0.6 |
| Rest of East and Southeast Asia | 12.3 | 264 | 1.8 | 94,172 | 3.3 | 0.3 |
| India | 5.5 | 2,098 | 14.7 | 504,000 | 17.5 | 0.4 |
| Bangladesh | –0.2 | 121 | 0.8 | 34,359 | 1.2 | 0.4 |
| Pakistan | 2.5 | 196 | 1.4 | 75,093 | 2.6 | 0.3 |
| Rest of South Asia | – | 82 | 0.6 | 21,556 | 0.8 | 0.4 |
| Asia | 0.067 | 8,074 | 56.5 | 1,715,906 | 59.7 | 0.5 |
| Brazil | 0.5 | 1,306 | 9.1 | 96,000 | 3.3 | 1.4 |
| Southern Cone | 5.5 | 607 | 4.2 | 44,970 | 1.6 | 1.3 |
| Andean | – | 315 | 2.2 | 63,023 | 2.2 | 0.5 |
| Mexico | 2.5 | 518 | 3.6 | 52,000 | 1.8 | 1.0 |
| Central America | – | 243 | 1.7 | 30,320 | 1.1 | 0.8 |
| Caribbean | – | 70 | 0.5 | 13,924 | 0.5 | 0.5 |
| Latin America and the Caribbean | 2.1 | 3,058 | 21.4 | 300,237 | 10.5 | 1.0 |
| **Total** | | **14,279** | **100.0** | **2,872,147** | **100.0** | **0.5** |

Source: Compiled by author from ASTI (2010–11), World Bank (2011b), and Heston, Summers and Aten (2011).

First, to project historical trends, historical growth rates of R&D investment during the 2000s were used (Table 3). Second, the position of countries showing high growth rates was checked against a ranking of innovation capacity measured using Días Avila and Evenson's (2010) invention-innovation (II) capital index, based on two indicators: agricultural scientists per unit of cropland, and R&D as a percentage of GDP. Días Avila and Evenson (2010) classify countries by assigning II index values of between 2 and 6, with 6 being the highest level of innovation capacity. Angola, Ethiopia, Guinea-Bissau, Mozambique, Namibia, Niger, Guinea-Bissau, and Sudan are the countries with the lowest innovation capacity in SSA, with an II of 2 in 1990. At the other extreme, Botswana, Kenya, Malawi, and South Africa are the countries with the highest II value (an II of 5). Other major countries scoring high in 1990 (an II of 4) are Cameroon, Côte d'Ivoire, Ghana, Guinea, Mali, Nigeria, Senegal, Tanzania, and Uganda. Since, in general, countries showing high R&D investment growth rates during the 2000s are mostly those with high II indexes, growth is projected using observed growth rates, assuming that countries with high II indexes and high investment growth will be the main innovators in agriculture in the coming years.

Figure 1 shows the evolution of the shares of SSA countries and regions in total regional agricultural R&D investment. Assuming a continuation of investment trends after 2000, the model projects a stable share for Nigeria, as the largest regional investor, and growing participation for Ghana, Kenya, South Africa, Tanzania, and Uganda.

**Figure 1. Projected evolution of the contribution of different countries and subregions to total R&D investment in Sub-Saharan Africa based on historical R&D growth rates, 2010–50**




Source: Compiled by author based on model simulations.

The impact of past investment in agricultural R&D on several performance indicators for SSA countries and subregions is presented in Table 4. Ghana and Kenya are projected to be the best performing countries in the region, with the highest per capita growth rates of agricultural production, the highest poverty reduction rates, and no changes in agricultural imports. Central Africa (including Angola), Ghana, Kenya, South Africa, Tanzania, and Uganda also show high growth rates of agricultural output per capita (higher than 2 percent) and remarkable rates of poverty reduction. On the other hand, agricultural output per capita in the Democratic Republic of Congo, Madagascar, the Sahel, and Sudan virtually continue to stagnate, with per capita output growth rates close to zero and high incidences of poverty compared with the best performing countries.

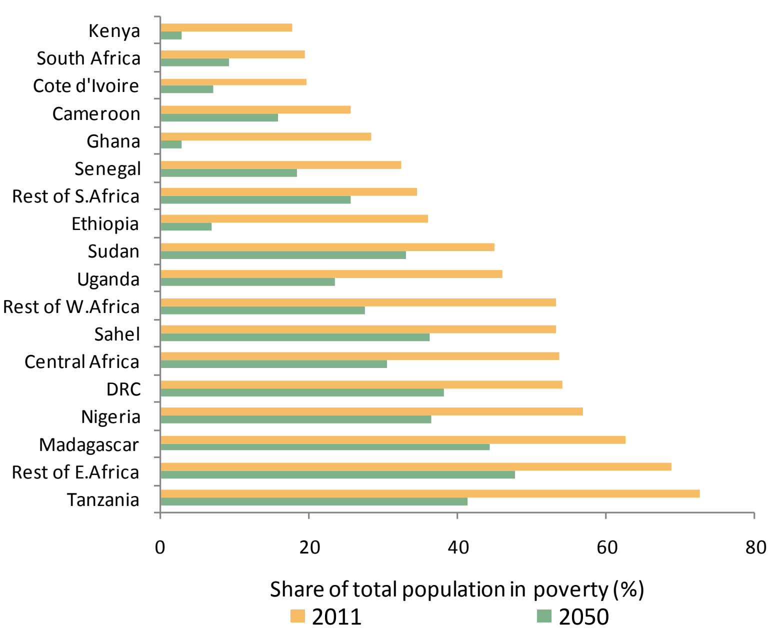
**Table 4. Projected yearly changes in various indicators for Sub-Saharan African countries and subregions under a baseline scenario, 2010–50**

| Country/region | Change in total output (%) | Change in output per capita (%) | Change in imports per capita (%) | Change in poverty headcount (%) |
|---|---|---|---|---|
| Nigeria | 2.65 | 0.37 | –0.86 | –1.17 |
| Ghana | 4.19 | 2.18 | 0.01 | –5.86 |
| Côte d'Ivoire | 3.47 | 1.51 | –0.13 | –2.68 |
| Cameroon | 2.51 | 0.61 | –0.42 | –1.27 |
| Senegal | 2.98 | 0.71 | –1.68 | –1.50 |
| Sahel | 2.74 | 0.03 | –1.41 | –1.01 |
| Ethiopia | 3.75 | 2.02 | 7.09 | –4.27 |
| Sudan | 2.02 | –0.01 | –0.79 | –0.81 |
| Kenya | 4.36 | 1.99 | 0.30 | –4.74 |
| Uganda | 3.58 | 0.80 | 0.58 | –1.76 |
| Tanzania | 3.34 | 0.55 | –0.13 | –1.48 |
| Rest of East Africa | 2.41 | 0.09 | –0.94 | –0.96 |
| South Africa | 2.26 | 1.55 | 0.27 | –1.95 |
| Madagascar | 2.49 | –0.06 | –0.15 | –0.91 |
| Rest of West Africa | 3.09 | 0.91 | –1.04 | –1.72 |
| Democratic Republic of Congo | 2.35 | 0.04 | –0.53 | –0.92 |
| Central Africa | 2.90 | 0.72 | –1.55 | –1.49 |

Source: Compiled by author based on model simulations.
Note: Scenario is based on an allocation of agricultural R&D investment across countries and subregions according to actual investments for the 2001–09 period.

Reduction in the incidence of poverty is very different across countries and subregions (Figure 2). Sustained agricultural growth in the best performing countries, as projected by the model, results in a significant reduction in the incidence of poverty. Côte d'Ivoire, Ethiopia, Ghana, Kenya, and South Africa, will be able to reduce the poverty headcount to less than 10 percent in the next 40 years—figures comparable to those in some of the fast-growing or middle-income countries in Asia and Latin America.

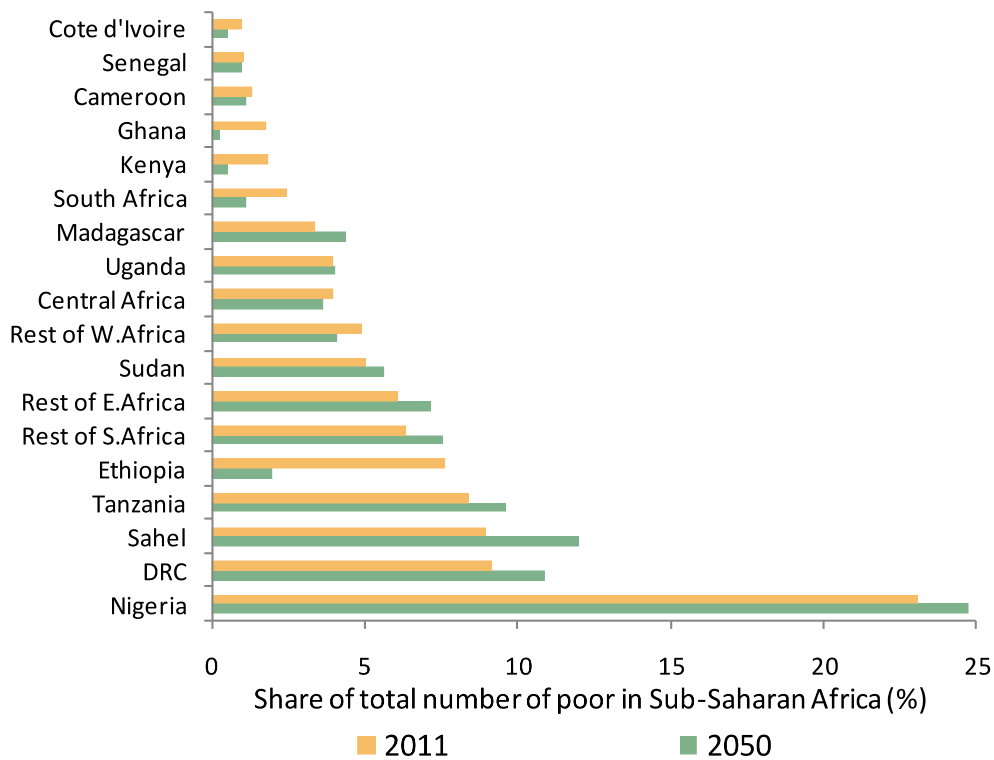
**Figure 2. Comparison of poverty incidence in Sub-Saharan Africa by country and subregion, 2011 and 2050**




Source: Compiled by author based on model simulations.
Note: DRC is the Democratic Republic of Congo. Data are based on the share of the population in poverty.

The differences observed in performance in agricultural production between countries will not significantly change the regional distribution of the total number of poor people (Figure 3). As of 2011, 57 percent of the total number of poor people in SSA live in four regions/countries: Ethiopia, the Democratic Republic of Congo, Nigeria, Tanzania, and the Sahel. In 40 years, only Ethiopia will have moved off this list, but poverty will still be concentrated in Nigeria, the Sahel, the Democratic Republic of Congo, and Tanzania (48 percent of the total number of poor people in SSA).

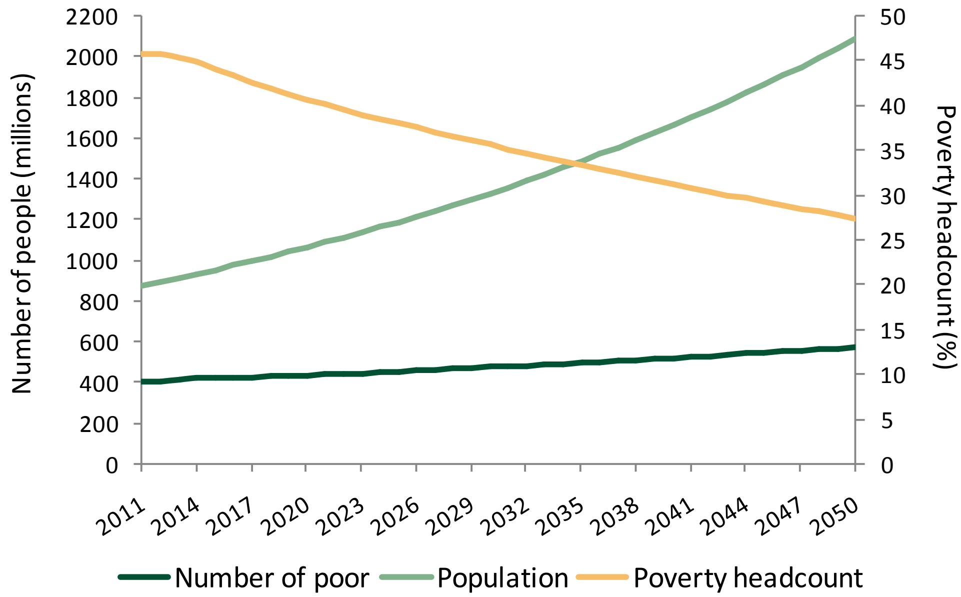
**Figure 3. Country and subregional shares of total number of poor people in Sub-Saharan Africa, 2011 and 2050**




Source: Compiled by author based on model simulations.
Note: DRC is the Democratic Republic of Congo.

Despite the good performance of some of SSA's largest countries, the projected number of poor people in 2050 increases from 400 million to almost 600 million, whereas the poverty headcount falls from 46 to 27 percent (Figure 4). In sum, current patterns and levels of agricultural R&D investment in SSA will result in substantial improvements in agricultural growth and poverty incidence in the best performing countries; however, the total number of poor people in the region will remain high, with poverty concentrated in poorly performing regions. How might these results change under a scenario that doubles current levels of total R&D investment in the region? This is explored in the next section.

**Figure 4. Projected evolution of the total number of poor people in Sub-Saharan Africa, 2011–50**

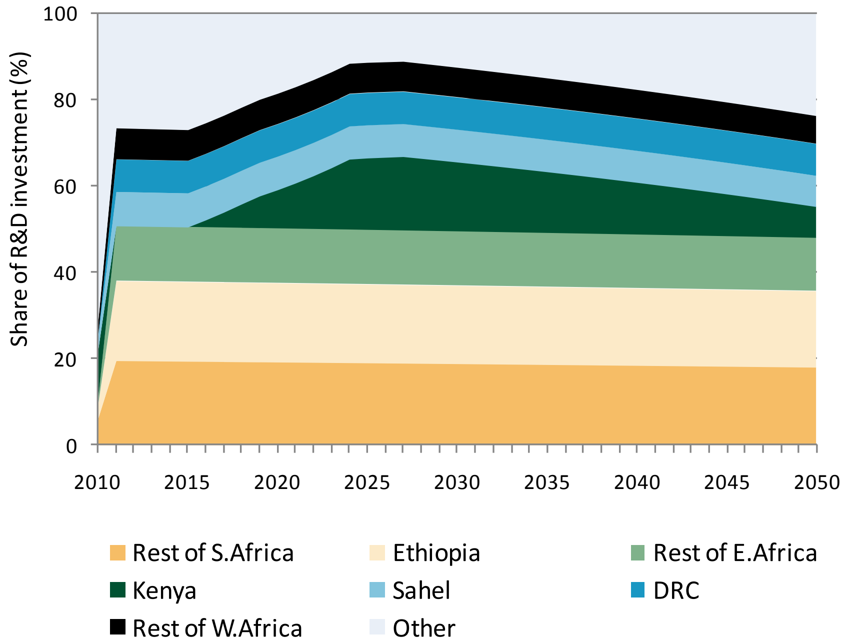



Source: Compiled by author based on model simulations.

## 5. THE IMPACT OF DOUBLING AGRICULTURAL R&D INVESTMENT IN SUB-SAHARAN AFRICA

How much do current R&D investment levels limit possibilities to accelerate growth and reduce poverty in SSA? In this section, two contrasting scenarios are explored that compare the impact of doubling current yearly R&D investments in SSA—an increase from the estimated of 1,800 million 2005 purchasing power parity (PPP) dollars, to PPP$3,600 million. In this first scenario, increased investments are allocated across countries according to their present shares of total regional investment. The only difference between this scenario and the baseline is the level of investment. The second scenario also doubles total R&D investment levels in SSA, but instead of allocating investment across countries according to historical shares, it allocates the increased funding to maximize regional welfare (Figure 5). Figure 5 also shows the historical allocation of investment at the beginning of the period (2010), and how optimal allocation changes priorities beginning in 2011. The optimal allocation prioritizes Ethiopia, the Rest of East Africa, and the Rest of Southern Africa, giving them 50 percent of the region's R&D funding. The Democratic Republic of Congo, Kenya, and the Sahel also receive a significant share of total investment, with a peak by the middle of the period.

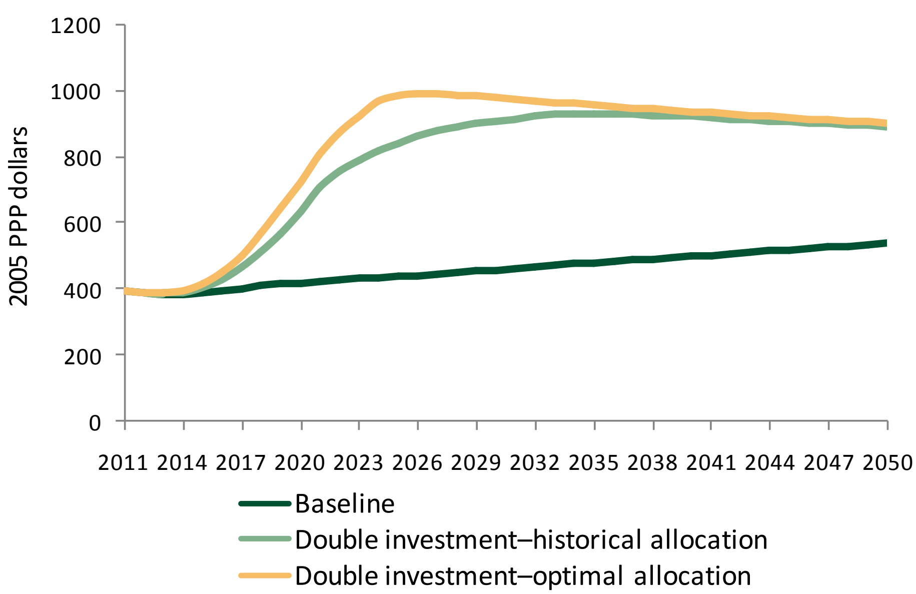
**Figure 5. Allocation of R&D investment in Sub-Saharan Africa under a scenario that maximizes regional welfare, 2010–50**




Source: Compiled by author based on model simulations.
Note DRC indicate Democratic Republic of Congo.

How does R&D allocation affect the performance of agricultural production in SSA? Figure 6 presents the evolution of agricultural output per capita, contrasting growth under a scenario of efficient funding allocation with one based on historical allocations and projected baseline levels of output per capita. The main difference between the historical and optimal allocation scenarios is that output in the optimal allocation scenario increases faster at the beginning of the period.

**Figure 6. Projected evolution of agricultural output per capita under three scenarios, 2010–50**

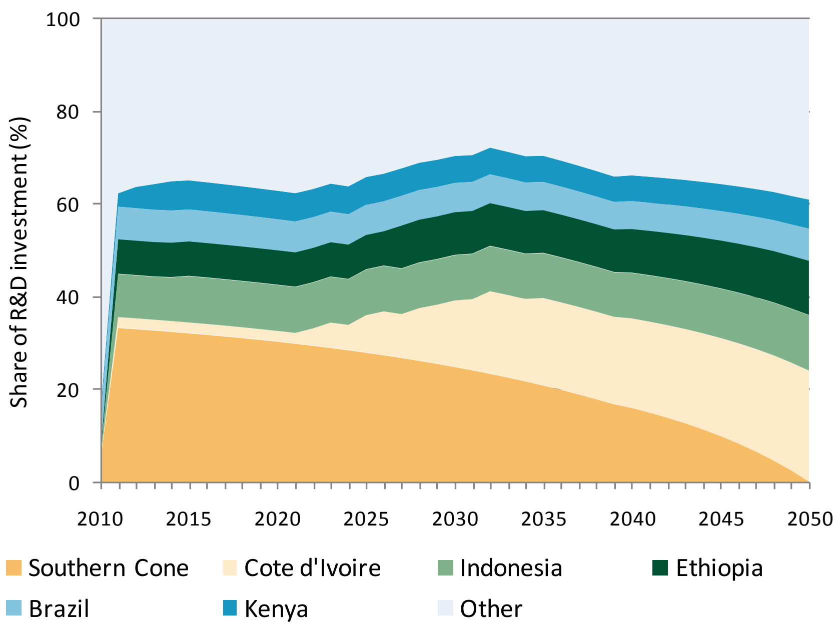



Source: Compiled by author based on model simulations.

## 6. EFFICIENT GLOBAL ALLOCATION OF AGRICULTURAL R&D INVESTMENT AMONG THE COUNTRIES AND SUBREGIONS OF SUB-SAHARAN AFRICA

This section explores efficient agricultural R&D investment at a global level expanding the analysis to include Asia and Latin America. Figure 7 shows the projected contributions for selected SSA countries, Brazil and the Southern Cone of South America, and Indonesia resulting from a doubling of current total investment from approximately 16 to 32 billion of 2005 PPP dollars, while at the same time allocating this investment among countries to maximize welfare. These shares are compared with historical allocations for 2010. At the global level, some of the major agricultural producers of SSA receive a significant share of total R&D investment (Côte d'Ivoire, Ethiopia, Kenya), together with the most efficient Latin American producers (the Southern Cone and Brazil) and Indonesia.

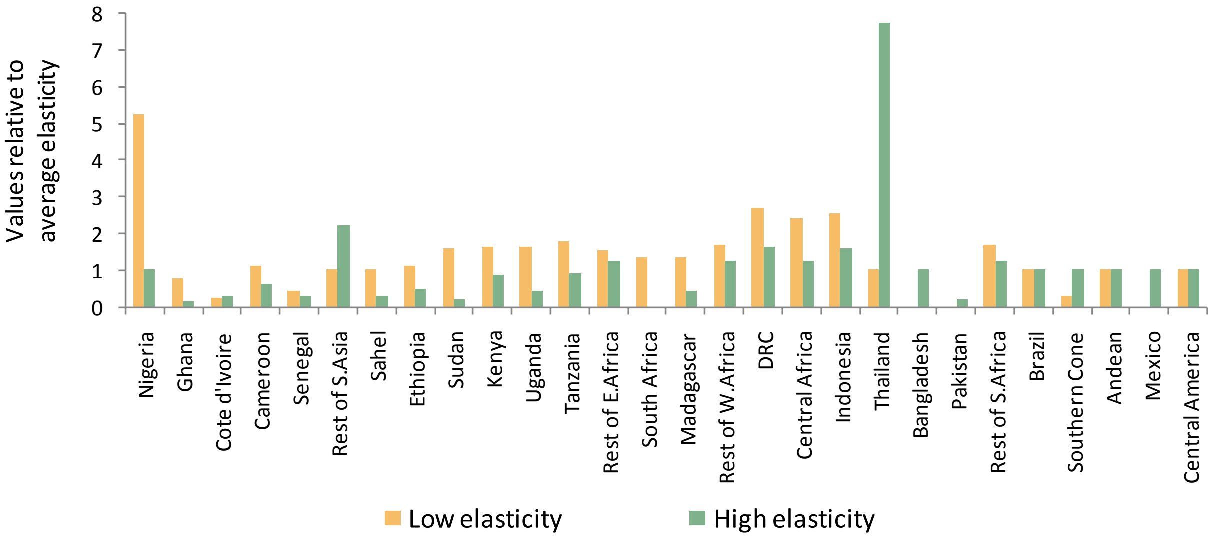
**Figure 7. Allocation of R&D investment under a scenario that maximizes welfare for selected SSA countries, Brazil and the Southern Cone, and Indonesia, 2010–50**




Source: Compiled by author based on model simulations.

Given that the results crucially depend on estimated R&D elasticities, results in the previous scenario are also compared with those obtained using two extreme values of elasticities for SSA countries. These extreme values are those that bound the 95 percent confidence interval of the estimated elasticity in Table 1. Figure 8 shows results of optimal R&D investment allocation with these two extreme elasticity values. Optimal allocation of investment appears to fall within a close range of those obtained using average elasticity values in most countries. Exceptions are Nigeria and Thailand, which receive higher investments with low and high elasticity values, respectively. Figure 9 compares the evolution of the number of poor people in SSA when R&D investments are optimally allocated among developing regions using three different elasticities. Results aggregated at the regional level appear to be robust with respect to changes in elasticity values.

**Figure 8. Comparison of optimal allocation of R&D investment with different R&D elasticities**




Source: Compiled by author based on model simulations.
Note: DRC indicate Democratic Republic of Congo. Values are relative to average.

## 7. CONCLUSIONS

This paper analyzes the effect of agricultural R&D investment on growth and poverty alleviation in developing regions to simulate how much investment is required, and how it can be allocated among different regions to maximize agricultural output gains and poverty reduction. To do so, it utilizes a model that allocates R&D investment across developing regions, maximizing welfare. A first conclusion to be drawn from the results is the importance of efficiently targeting the allocation of agricultural R&D investment across regions. The analysis for SSA shows rather different results than those for the global level, as present R&D investment allocation differs significantly from the optimal social allocation. Evidence from the model simulations suggests that higher priority should be given to investment in East Africa (Ethiopia, Kenya, and the Rest of East Africa), increasing this subregion's share of SSA's R&D investment. Projected future trends in agriculture growth resulting from past efforts in R&D investment imply that countries like Ethiopia, Ghana, and Tanzania could achieve substantial growth in agriculture and poverty reduction. On the other hand, lagging regions like the Sahel are likely to perform poorly in the future, with no growth in agricultural output per capita and higher shares of the regions total number of poor people. Optimal allocation of R&D investment among developing countries shows that maximizing welfare for these countries requires the allocation of a significant portion of total investment to some of SSA's large agricultural producers.

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## APPENDIX A

**Appendix Table A1. Country mapping of the 41 regions included in the model**

| | Region/country | Included countries |
|---|---|---|
| East Africa | Ethiopia | Ethiopia |
| | Kenya | Kenya |
| | Sudan | Sudan |
| | Tanzania | Tanzania |
| | Uganda | Uganda |
| | Rest of East Africa | Burundi, Djibouti, Eritrea, Rwanda, Somalia |
| Southern Africa | South Africa | South Africa |
| | Madagascar | Madagascar |
| | Rest of Southern Africa | Botswana, Lesotho, Malawi, Mozambique, Namibia, Swaziland, Zambia, Zimbabwe |
| West and Central Africa | Central Africa | Angola, Central African Republic, Congo, Gabon |
| | Cameroon | Cameroon |
| | Côte d'Ivoire | Côte d'Ivoire |
| | DRC | Democratic Republic of Congo |
| | Ghana | Ghana |
| | Nigeria | Nigeria |
| | Sahel | Burkina Faso, Chad, Gambia, Guinea-Bissau, Mali, Mauritania, Niger |
| | Senegal | Senegal |
| | Rest of West Africa | Benin, Cape Verde, Eq. Guinea, Guinea, Liberia, Sierra Leone, Togo |
| South and Southeast Asia | India | India |
| | Bangladesh | Bangladesh |
| | Pakistan | Pakistan |
| | China | China |
| | Indonesia | Indonesia |
| | Rest of East Asia | Cambodia, Democratic Rep. Of Korea, Lao, Malaysia, Philippines, Korea, Singapore, Vietnam |
| Latin America and the Caribbean | Andean countries | Bolivia, Colombia, Ecuador, Peru, Venezuela |
| | Southern Cone | Argentina, Chile, Paraguay, Uruguay |
| | Brazil | Brazil |
| | Central America | Belize, Costa Rica, El Salvador, Guatemala, Honduras, Nicaragua, Panama |
| | Caribbean | Dominican Republic, Haiti, Jamaica, Trinidad and Tobago |
| | Mexico | Mexico |
| Middle East and North Africa | Egypt | Egypt |
| | Middle East | Bahrain, Iran, Iraq, Jordan, Kuwait, Lebanon, Oman, Qatar, Saudi Arabia, Syria, Turkey, United Arab Emirates, Yemen |
| | North Africa | Algeria, Libya, Morocco, Tunisia |
| High-income countries | Australia–New Zealand | Australia and New Zealand |
| | Japan | Japan |
| | Europe | Austria, Belgium, Denmark, Finland, France, Germany, Greece, Iceland, Ireland, Italy, Netherlands, Norway, Portugal, Spain, Sweden, Switzerland, United Kingdom |
| | United States-Canada | United States, Canada |
| Other | Former USSR and Eastern Europe | Albania, Armenia, Azerbaijan, Belarus, Bosnia and Herzegovina, Bulgaria, Croatia, Czech Rep., Czechoslovakia, Estonia, Georgia, Hungary, Kazakhstan, Latvia, Lithuania, Montenegro, Polan, Moldova, Romania, Russia, Serbia, Montenegro, Slovakia, Slovenia, Tajikistan, Macedonia, Turkmenistan, Ukraine, Uzbekistan, Yugoslav SFR |
| | Rest of the World | American Samoa, Antigua and Barbuda, Aruba, Bahamas, Barbados, Bermuda, British Virgin Islands, Brunei, Cayman Islands, Comoros, Cook Islands, Cyprus, Dominica, Falkland Islands, Faroe Islands, Fiji, French Polynesia, Grenada, Guam, Maldives, Malta, Mauritius, Mongolia, Nauru, Netherlands Antilles, New Caledonia, Niue, Norfolk Island, Papua New Guinea, St. Kitts and Nevis, St. Lucia, St. Pierre and Miquelon, St. Vincent and the Grenadines, Samoa, St. Tome and Principe, Seychelles, Solomon Islands, Timor-Leste, Tonga, Tuvalu, Vanuatu |

Source: Compiled by author.

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The Agricultural Science and Technology Indicators (ASTI) initiative compiles, analyzes, and publishes data on levels and trends in agricultural R&D investments, capacities, and institutional arrangements in developing countries. ASTI is managed by the International Food Policy Research Institute (IFPRI) and involves collaborative alliances with many national and regional R&D agencies.

Jointly convened by ASTI/IFPRI and the Forum for Agricultural Research in Africa (FARA), the conference, "Agricultural R&D—Investing in Africa's Future: Analyzing Trends, Challenges, and Opportunities," brought together experts and stakeholders from the region to contribute their expertise for the purpose of distilling new insights and creating synergies to expand the current knowledge base. The themes under focus were (1) why African governments under invest in agricultural R&D; (2) how human resource capacity in agricultural R&D can be developed and sustained; (3) how institutional structures can be aligned and rationalized to support agricultural R&D; and (4) how the effectiveness of agricultural R&D systems can be measured and improved.

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This paper has been peer reviewed and may also have been slightly revised after the conference. Any opinions stated herein are those of the author(s) and are not necessarily endorsed by or representative of IFPRI or FARA.

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