AGRICULTURE

# Agricultural Research, Productivity, and Food Prices in the Long Run

A reinvestment in agricultural R&D is critical to ensuring sufficient food for the world in the coming decades.

**Julian M. Alston,[1]* Jason M. Beddow,[2] Philip G. Pardey[2]†**

In a recent update of earlier estimates (*1*), the Food and Agriculture Organization (FAO) of the United Nations reported that more than one billion people now suffer malnutrition (*2*). Despite declines in food prices from their 2008 highs, local prices in many developing countries are still high by recent historical standards. Long-run trends in global food commodity prices are driven by differential rates of growth in the supply and demand for food crops, feed, and livestock products.

Growth in demand for agricultural commodities largely stems from growth in demand for food, which is driven by growth in population and per capita incomes (especially the economic growth of the fast-growing economies of Asia), coupled with new demands for biofuels. Growth in supply of agricultural commodities is primarily driven by growth in productivity, especially as growth in the availability of land and water resources for agriculture has become more constrained. Thus, agricultural productivity growth will be a pivotal determinant of long-term growth in the supply, availability, and price of food over the coming decades.

Here, we document a slowdown in growth of agricultural productivity and grain yields. If this slowdown in productivity persists, it could have profound implications for food price trends in the future.

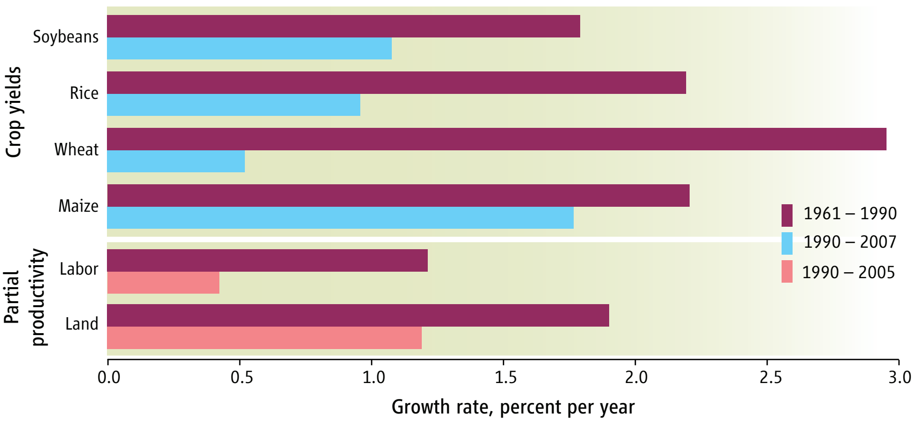


### Global Crop Yields and Productivity

Global yields for maize, rice, wheat, and soybeans (in metric tons per harvested hectare) grew rapidly from 1961 to 2007: Maize and wheat yields each grew by a factor of 2.6, while rice and soybean yields increased by a factor of 2.2 and 2.0, respectively (*3*). However, for all four crops, in both developed and developing countries, rates of yield growth were slower during 1990 to 2007 than during 1961 to 1990 (see graph, below, and table S1). A slowdown in crop yield growth was seen in more than half of the countries that grew these four crops. More critically, compared with all producing countries, a higher proportion of the top 10 producing countries experienced a slowdown for all four crops (*4*).

Global land productivity, reflecting worldwide output of 185 crop and livestock commodities per harvested and pastured area, was 2.4 times in 2005 what it was in 1961 (equivalent to growth of 1.96% per year). Labor productivity, the output per agriculture worker, grew by a factor of 1.7 during that span (1.20% per year growth) (table S2). These productivity developments reflect relatively slow growth in the use of agricultural land and labor (0.31% and 1.07% per year, respectively), compared with growth in global agricultural output (2.27% per year) (table S2).

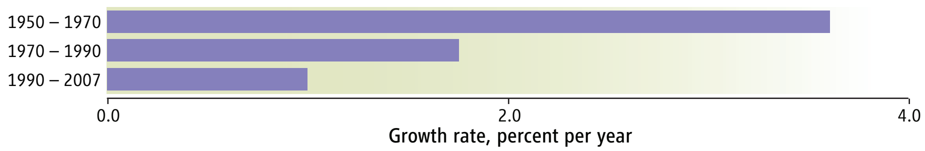
In parallel with global crop yields, global land productivity grew at a slower pace from 1990 to 2005 (1.82% per year) than from 1961 to 1990 (2.03% per year) (table S2). Labor productivity increased at a faster rate from 1990 to 2005 than from 1961 to 1990 (1.36% versus 1.12% per year, respectively) (table S2). These world totals are influenced by the significant, and in many respects exceptional, case of China, where land and labor productivity growth has accelerated




**Global yield and agricultural productivity growth rates**, percent per year for 1961 to 2007. Yield is measured as metric tons per hectare. Labor and land productivity are total agricultural output per agricultural worker and agricultural area, respectively, excluding China. Total agricultural output was derived using 1999 to 2001 price weights. Authors' calculations are based on data from (*4*). See notes accompanying table S1 and table S2.

[1]Department of Agricultural and Resource Economics and Robert Mondavi Institute Center for Wine Economics at the University of California, Davis, CA 95616, USA. [2]Department of Applied Economics and International Science and Technology Practice and Policy (InSTePP) Center at the University of Minnesota, St. Paul, MN 55108, USA.

*Authorship is alphabetical.
†To whom correspondence should be addressed. E-mail: ppardey@umn.edu




**Percent annual growth of U.S. public agricultural R&D spending** for 1950 to 2007. The underlying public agricultural R&D spending data are adjusted to reflect 2000 prices. Public agricultural R&D includes intramural USDA research and research conducted at the state agricultural experiment stations. Extracted and compiled by the authors using (*15*–*17*).

recently (*5*). If China is left out, global land and labor productivity growth has been substantially slower since 1990 than during the previous three decades (see graph, p. 1209, and table S2). Among the top 20 producing countries (according to their 2005 value of agricultural output), land and labor productivity grew substantially more slowly from 1990 to 2005 than from 1961 to 1990, again, once the case of China is set aside.

### Agricultural Research and Development

Many factors may have contributed to the slowdown in agricultural productivity growth. Changes in weather or climate, land degradation, shifts of the location of production to less favorable environments, farmer responses to resource scarcity or higher prices of inputs, changes in public institutions [e.g., in China and the former USSR (*5*–*7*)], and evolving pests and diseases may all have contributed.

Agricultural R&D also is an important element of the story, a critical policy instrument that governments can apply to influence the path of agricultural productivity. Organized public and private investment in agricultural R&D was a primary driver of the comparatively rapid growth in agricultural productivity experienced in the latter half of the 20th century (*8*, *9*). The interactions are complex, with long and uncertain time lags between initial investment in research and realization of the returns. But although it takes a long time, perhaps decades, for R&D to affect productivity, it then typically affects productivity for decades more. These effects may be subtle. Much investment in agricultural R&D is of a "maintenance" type, designed not to increase yields so much as to prevent yields from declining in the face of coevolving pests and diseases or other environmental changes (*10*).

Despite the long lags, hundreds of cost-benefit studies have reported that investments in agricultural R&D have yielded high returns (*8*, *9*, *11*). Such studies have indicated that the world has persistently underinvested in agricultural R&D (*8*, *11*, *12*) and have been cited by economists to justify an increased rate of growth in agricultural R&D spending (*8*), which may help restore productivity growth and ameliorate hunger and poverty (*12*). Instead, we have seen a slowdown in the growth rate of public agricultural R&D investments (see graph, above) and a change in the balance between private and public investments to increase the private share. Moreover, funds have been redirected away from farm productivity toward other concerns, such as the environmental effects of agriculture; food safety and other aspects of food quality; and the medical, energy, and industrial uses of agricultural commodities (fig. S1). For example, in 1975, an estimated 66% of all research conducted by the state agricultural experiment stations in the United States was directed to maintaining and enhancing farm productivity; by 2007, this share had slipped to 57%.

Data for other developed countries show patterns somewhat consistent with those in the United States (*13*). In the latter half of the 1990s, public agricultural R&D was massively reduced in Japan and also, to a lesser degree, in several European countries.

In the past, most countries (especially the poorest ones) have relied heavily on spillovers of knowledge and technology resulting from agricultural R&D undertaken by a small number of developed countries. Thus, a continuation of recent trends in funding, policy, and markets is likely to have significant effects on long-term farm productivity for food staples in developed and developing countries alike (*12*). A revitalization of agricultural R&D investments in developed countries can be justified on narrow cost-benefit criteria (*12*). In addition, it will contribute to the global public good by restoring and sustaining productivity growth over the long run, which in turn will mitigate hunger and poverty and, at the same time, reduce pressure on the natural resource base.

#### References and Notes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2. FAO, "More people than ever are victims of hunger" (Press release, FAO, Rome, 2009); www.fao.org/fileadmin/user_upload/newsroom/docs/Press%20release%20june-en.pdf.
3. Unless otherwise noted, empirical evidence presented herein was developed by the authors drawing from (*4*, *14*) for yield and productivity estimates and (*15*–*17*) for trends in U.S. agricultural R&D. For any given year and geographic unit in question, data reflect only one observation. Total growth of yields, productivity, and R&D expenditures over multiple-year periods (the difference between end-year and initial-year observations) is expressed as annual rates to allow comparisons between periods of different lengths. The nature of these data (i.e., single-valued, not averages calculated from samples) limits reporting of additional statistics. See supporting online materials for additional data and details.
4. FAO, FAOSTAT database; http://faostat.fao.org.
5. While notable in their own right and of significance in terms of global totals, developments in China (and the former U.S.S.R.) were exceptional, with unique, essentially one-off attributes. The massive institutional changes in China (notably the introduction of the household responsibility system into Chinese agriculture in the late 1970s) had a sizable, one-shot (albeit enduring) effect on productivity developments in that country [for example, see (*6*)]. Impacts on agricultural productivity growth and downsizing of agriculture in the economies of the former U.S.S.R. after the breakup of the Soviet Union are documented and discussed by (*7*) among others.
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16. USDA, *Inventory of Agricultural Research* (USDA, Washington, DC, various years); http://cris.csrees.usda.gov/.
17. USDA (CRIS), *Manual of Classification for Agricultural and Forestry Research, Education, and Extension* (USDA, Washington, DC, various years); http://cris.csrees.usda.gov/manual.html.


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#### Supporting Online Material

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