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Public Agricultural Research Spending and Future U.S. Agricultural Productivity Growth: Scenarios for 2010-2050

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Major Findings

- By 2050, global agricultural demand is projected to grow by 70-100 percent due to population growth, energy demands, and higher incomes in developing countries. Meeting this demand from existing agricultural resources will require raising global agricultural total factor productivity (TFP)[1] by a similar level. Maintaining the U.S. contribution to global food supply would also require a similar rise in U.S. agricultural TFP.
- TFP growth in U.S. agriculture is predicated on long-term investments in public agricultural research and development (R&D). Productivity growth also springs from agricultural extension, farmer education, rural infrastructure, private agricultural R&D, and technology transfers, but the force of these factors is compounded by public agricultural research.
- The rate of TFP growth (and therefore output growth) of U.S. agriculture has averaged about 1.5 percent annually over the past 50 years. Stagnant (inflation-adjusted) funding for public agricultural research since the 1980s may be causing agricultural TFP growth to slow down, although statistical analyses of productivity growth trends are inconclusive.
- ERS simulations indicate that if U.S. public agricultural R&D spending remains constant (in nominal terms) until 2050, the annual rate of agricultural TFP growth will fall to under 0.75 percent and U.S. agricultural output will increase by only 40 percent by 2050. Under this scenario, raising output beyond this level would require bringing more land, labor, capital, materials, and other resources into production.
- Additional public agricultural R&D spending would raise U.S. agricultural productivity and output growth. Raising R&D spending by 3.73 percent annually (offsetting the historical rate of inflation in research costs) would increase U.S. agricultural output by 73 percent by 2050. Raising R&D spending by 4.73 percent per year (1-percent annual growth in inflation-adjusted spending) would increase output by 83 percent by 2050.

[1]Total factor productivity (TFP) is the broadest measure of productivity. It compares the total output of a sector to the total land, labor, capital, and material inputs used to produce that output. Increases in TFP imply more output is forthcoming from a given level of inputs, or, equivalently, fewer inputs are required to produce the same output. Growth in TFP is considered to be an indicator of the rate of technical change in a sector.

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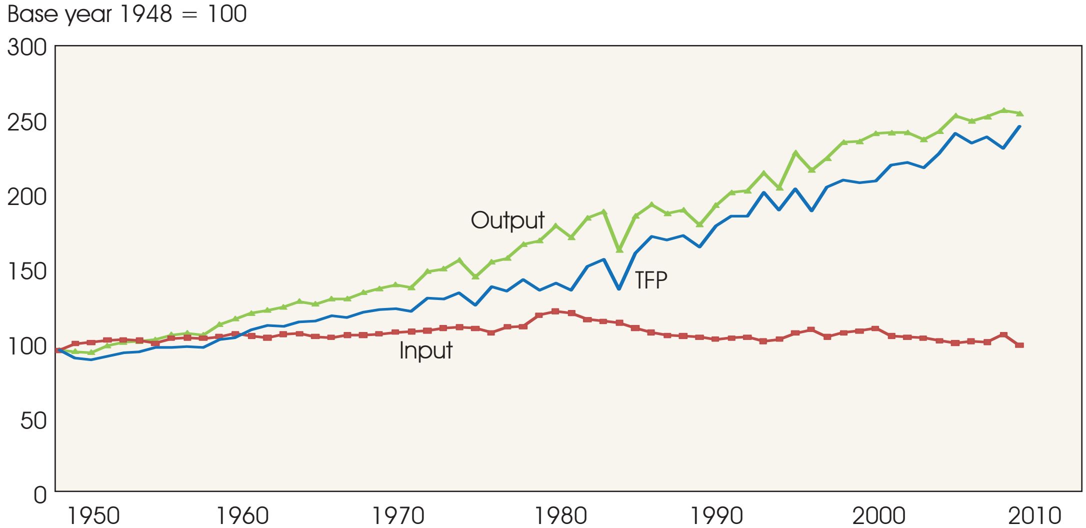
Figure 1

U.S. agricultural output, input, and TFP indexes



Source: U.S. Department of Agriculture, Economic Research Service.

Productivity growth accounts for nearly all U.S. agricultural growth

Total factor productivity (TFP) is a good indicator of technological change. It measures the efficiency with which all inputs (land, labor, capital, and materials) are combined to produce total outputs (all crop and livestock commodities). In U.S. agriculture, growth in TFP is nearly synonymous with growth in output since the overall size of the resource base has barely increased over the last 60 years. Between 1948 and 2008, the average annual growth rate in U.S. agricultural output was 1.58 percent and the average annual growth rate in TFP was 1.52 percent. As a result, total agricultural output in 2008 was 2.5 times that of 1948 (figure 1).

R&D spending spurs TFP growth

Growth in TFP is strongly associated with the adoption of new technologies that raise yields or lower costs. Public investment in agricultural R&D is a major source of new agricultural technology; it also complements (raises returns to) other productivity-enhancing activities like extension, education, infrastructure, and private R&D. While private-sector investment in agricultural R&D also contributes new technology, much of this contribution is already accounted for in the way the inputs are measured in constructing the estimates of TFP.[2] Moreover, studies have shown that private R&D depends critically on government and university investments in science and technology.[3] Thus, even if the quality-adjusted measures of TFP do not fully net out the contributions of private R&D, if private R&D follows (responds positively to) trends in public R&D, then simulations using public R&D as the primary policy lever for future productivity growth should not be unduly biased. Nonetheless, the simulations reported here depend on these assumptions about private R&D: that its impacts are partially netted out of the TFP measure and that it follows trends in public R&D.

Statistical models of TFP growth treat R&D spending as "knowledge capital." As with physical capital, an R&D investment can affect productivity growth for several years (even decades), but eventually depreciates as technologies grow ineffective (e.g., new pests and diseases evolve) or obsolete. R&D investments typically begin boosting TFP within 3-5 years, with benefits peaking after 10 to 20 years, and with some impacts lasting as long as 50 years (Huffman and Evenson, 2006; Alston et al., 2010).

[2]New technologies from private R&D are partially embodied in the quality of the inputs (chemicals, machinery, seed, etc.) purchased by farmers. The TFP measure used in this study adjusts for such quality improvements in these inputs. In other words, it already nets out many of the productivity effects of private R&D.

[3]Public-sector research opens up new technological opportunities for the private sector to commercialize. One recent study found that "government expenditures in both basic biological research and agricultural and medical science create substantial spillovers for private firms…Indeed, opportunities created through public research are the principal source of growth in industry life sciences" (Wang, Xia and Buccola, 2009). Fuglie and Walker (2001) also found complementarity between public and private investments in crop genetic improvement, with public research in basic plant breeding spurring more private investment in crop variety development.

Agricultural R&D spending scenarios account for inflation in research costs

Between 1927 and 2009 (the period for which we have data), total spending by Federal and State agricultural research institutes on productivity-related agricultural research (excluding R&D on post-harvest, environmental, and rural development issues) rose at an average annual rate of 7.49 percent in nominal terms. If adjusted by the Consumer Price Index, then research spending rose by 4.37 percent per year. However, if inflation adjustments reflect the cost of doing research (i.e., scientist salaries, laboratory equipment, etc.), then real research spending rose by only 3.03 percent per year (i.e., research costs have been rising faster than the average price level of goods and services in the economy).

Estimates of R&D knowledge capital are based on real research spending (adjusted by the rate of inflation in the cost of research resources). Growth in public agricultural research spending slowed dramatically after the early 1980s and has declined by more than 20 percent since peaking in 1994 (figure 2). The growth in the stock of agricultural knowledge capital, which follows trends in research spending with a lag, peaked around 2005. Since then, knowledge capital stock has started to decline as current spending (creation of new knowledge capital) has failed to keep up with knowledge capital depreciation.

We simulate three possible scenarios for future public agricultural R&D expenditure for 2010-2050 (see Box for a description of the simulation model). These scenarios include total expenditures on productivity-oriented agricultural research by USDA research agencies and State agricultural experiment and veterinary medicine colleges from all sources of funding (USDA, other Federal and State governments, and others).

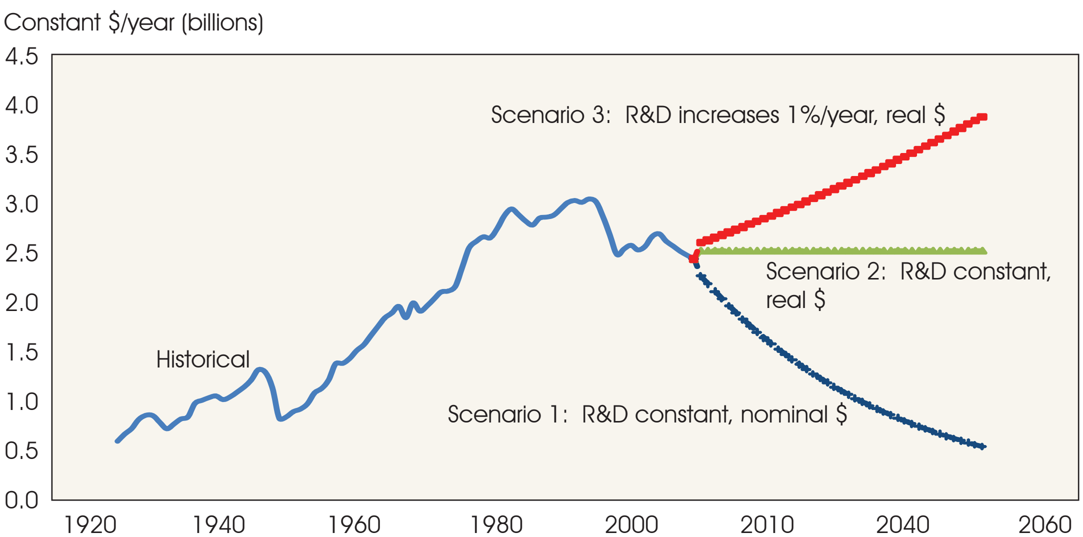
Scenario 1: Public research spending is constant in nominal terms at the 2005-09 average ($2.5 billion per year). This implies a decline in real research expenditure by 3.73 percent per year (the inflation rate in the cost of research resources over 1983-2009).[4] In other words, under this scenario, inflation reduces the effective amount of research effort.

Scenario 2: Public research spending is constant in real terms at the 2005-09 average. This implies that nominal expenditures for public agricultural research rise by about 3.73 percent per year to offset inflation in the cost of research.

[4]While the average rate of inflation in research costs over 1927-2009 was 4.46 percent, this has slowed in more recent years. To project research cost inflation in the future, we chose the average inflation rate in research costs during 1983-2009, or 3.73 percent per year.

Figure 2

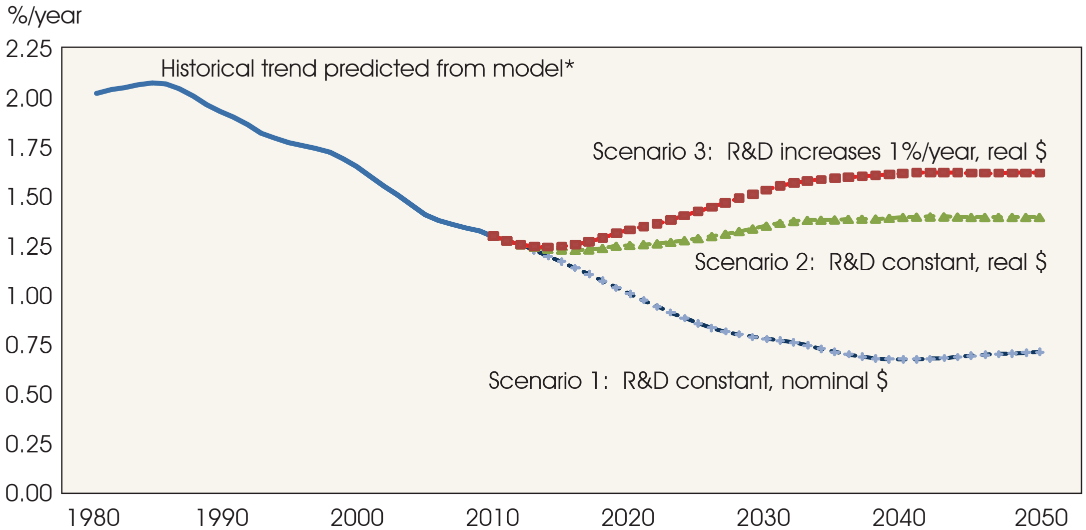
Productivity-oriented agricultural research expenditures



Source: Historical data from Huffman (2010) and 2010-2050 data from U.S. Department of Agriculture, Economic Research Service simulations.

Figure 3

TFP growth rate projections



* The graph shows the TFP growth rate predicted from the statistical model rather than the actual TFP growth rate for 1980-2008. Actual TFP growth is highly variable, ranging between -15% and + 15% for individual years. This variability is mainly due to weather.

Scenario 3: Public research spending increases by 1 percent per year in real terms (implying a nominal increase of about 4.73 percent per year). This 1-percent real growth rate is roughly equivalent to the rate of U.S. population growth (a proxy for growth in domestic agricultural demand). Real research expenditures rise, but more slowly than the rapid growth in real spending observed before the 1980s.

R&D Spending Must Rise to Maintain Historical Agricultural TFP Growth Rate

The resulting TFP projections under the three public R&D spending scenarios are shown in figures 3 and 4. Figure 3 shows the projected *annual growth rate* in agricultural TFP. The estimated historical trend based on our model shows a declining rate of TFP growth since peaking at just over 2 percent per year in the mid-1980s. By 2008, annual TFP growth was about 1.3 percent.[5] In each of the scenarios, rates of TFP growth increase or decrease from present levels and then level off after 2030 or 2040. Under scenario 1, the TFP growth rate declines to under 0.75 percent per year. Under scenario 2, TFP growth stabilizes at about 1.4 percent per year. Under scenario 3, TFP growth accelerates and reaches 1.6 percent per year by 2040.

Figure 4 translates TFP growth into an agricultural TFP index (base year of 2008=100) under alternative funding scenarios. It also shows the agricultural output level (relative to 2008 production) achievable if agriculture's current resource base remains unchanged. Under scenario 3, by 2050 U.S. agricultural output would be 83 percent higher than 2008 levels and under scenario 2, output would grow by 73 percent. As a point of comparison, current estimates suggest global food demand will increase between 70 and 100 percent by 2050 (Food and Agriculture Organization, 2006). Under scenario 1, however, with constant R&D funding (in nominal terms), U.S. agricultural output would increase by only about 43 percent between 2008 and 2050 using the current agricultural resource base. This would barely outpace the projected growth in U.S. population. By contrast, U.S. agricultural output would likely keep up with the growth in global demand under the higher R&D investment scenarios.

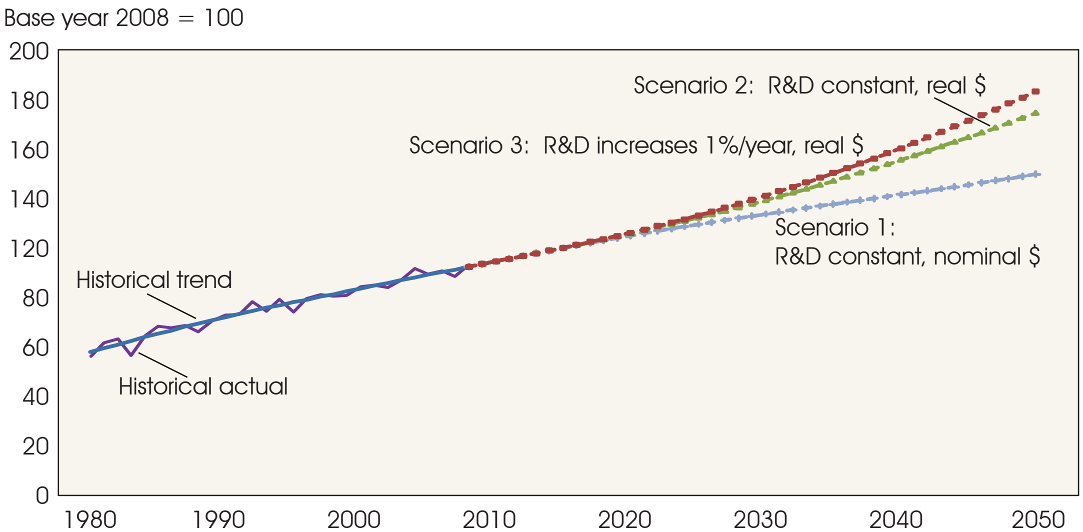
Another recent study (Alston et al. 2010) used different data and modeling assumptions to independently derive statistical relationships between public agricultural R&D spending and TFP growth. Their findings are broadly similar to our own: public spending on agricultural R&D will need to rise to maintain historical rates of productivity growth in U.S. agriculture.

[5]This apparent decline in TFP growth is based on the model used to project future TFP growth. All other factors were kept fixed except for the changes in R&D "knowledge capital" stock; therefore, the decline in the TFP growth rate reflects the erosion of R&D stocks, as hastened by the stagnation in R&D funding that began in the 1980s (see figure 2). Thus, the slowing of TFP growth in figure 3 after the mid-1980s reflects this model assumption; actual agricultural TFP growth may not have slowed if other contributing factors offset the decline in R&D capital.

Implications of a decline in the long-term growth rate in U.S. agricultural productivity are significant for both the United States and the world. Slower productivity growth will likely cause agricultural prices to rise, which would reduce global economic welfare and raise poverty in urban areas and among food-deficit rural households, especially in developing countries (Nelson et al., 2010). Rising prices would also increase pressure to expand agricultural cropland at home and abroad and input use on cropland would likely intensify. Such agricultural resource expansion and intensification could come with significant environmental costs, such as further impairment of soil and water quality, loss of biodiversity, and increased emissions of greenhouse gases (Foresight, 2011). Finally, agricultural exports may also decline as U.S. farmers lose competitiveness in international markets (Ball et al., 2010).

Figure 4

TFP index projections



How the estimates were derived

We use a model developed by ERS (Wang et al., 2010) along with research expenditures data from Wallace Huffman at Iowa State University. Huffman isolates the component of total public agricultural R&D associated with raising crop and livestock productivity and excludes other kinds of R&D (Huffman et al., 2001; Huffman and Evenson, 2006; Huffman, 2010).

Statistical models that link TFP to these investments treat R&D spending as "knowledge capital." Like physical capital, knowledge capital contributes to growth over a long period of time but eventually depreciates; it requires new R&D investment to be maintained and expanded. We use the assumptions developed by Huffman and colleagues to convert annual R&D investments, or flows, into R&D capital, or stocks. Under these assumptions, R&D investments influence R&D stocks, and therefore TFP, for up to 35 years.

We assume alternative scenarios for future public R&D funding to simulate future growth in U.S. agricultural total factor productivity to 2050. We use statistical relationships based on different productivity and investment patterns across States over 1980-2004 to estimate the effects of R&D stocks on productivity growth. These estimated relationships are used to project future TFP growth patterns given alternative assumptions about future R&D spending. Changes in current levels of public R&D spending affect future TFP growth only gradually since most of today's "knowledge capital stock" is the result of past, accumulated investment in R&D. In order to model the effects of different scenarios for R&D spending on future TFP growth, we hold the contributions to agricultural productivity from other sources—such as agricultural extension, farmer education, infrastructure, economies of scale, and technology transfer—constant and allow only the effects from public agricultural R&D to change.

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