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Is agricultural productivity slowing?

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ABSTRACT

Declining rates of growth in crop yields, slowing investment in agricultural research, and rising commodity prices has raised concerns of a general slowdown in global agricultural productivity. However, there is no evidence of a general slowdown in the rate of growth in agricultural output. Thus, for productivity to slow, input use in agriculture would have to be expanding at an accelerated rate. Available data suggest that growth rates in agricultural land, labor and inputs in total have been steadily slowing over time, leading to accelerated growth rates in their average productivities. Increased cropping intensity has compensated for declining growth in average yield per harvest to keep land productivity growth from falling. Most of the acceleration in world agricultural productivity growth has taken place in developing countries; for industrialized countries, long-term trends show gradually declining agricultural productivity growth.

1. Introduction

Improving agricultural productivity is essential for global food security. Raising agricultural yield eases pressure on land and avoids the Malthusian dilemma, while raising the productivity of agricultural labor in poor countries boosts income and stimulates broader economic development. By reducing the amount of land, labor, and other resources needed to produce food, higher agricultural productivity makes food cheaper and more plentiful, and has a powerful effect on poverty reduction.

For these reasons trends in national and global agricultural productivity are important to monitor and assess. Evidence of a productivity slowdown in agriculture could be a harbinger of higher food prices, greater pressure on the environment, and regression in progress toward meeting United Nations Sustainable Development Goals. Moreover, since the principal policy instrument for raising agricultural productivity is investment in research and development (R&D), which usually involves a long time lag to achieve impact, evidence of an emerging slowdown should be treated with urgency. It could take a decade or more to reverse such a trend through increased spending on R&D.

The prospect of a widespread and significant slowdown in agricultural productivity was raised in the World Development Report 2008 (World Bank, 2007), which claimed that annual growth rates in yield of rice, maize and wheat in developing countries had “slowed sharply since the 1980s” (p. 66). Alston et al. (2009) found that between 1961–1990 and 1990–2007, yield growth rates for these crops and soybeans had roughly halved world-wide, and that growth rates for overall land and labor productivity had slowed as well. They attributed the productivity slowdown primarily to declining growth rates in public spending on agricultural R&D, and warned of higher global food prices if trends weren’t reversed. Alston and Pardey (2014) extended this analysis with data through 2011 and continued to find a slowdown in crop yield. However, the evidence of a slowdown in overall cropland productivity growth was evident only if China was excluded from world data. The growth rate for agricultural labor productivity, on the other hand, had accelerated after 1990 for the world as a whole, for China, and for the next largest 29 countries (representing about 70% of global agricultural output), but registered a modest slowdown for the smallest 154 producing countries included in their data. Nonetheless, they concluded, “No one disputes the evidence that growth rates of crop yields and land and labor productivity have slowed for the world as a whole excluding China” (p. 12).

The agricultural productivity slowdown hypothesis, however, has not stood up when assessed against trends in agricultural total factor productivity (TFP). TFP takes a systems approach to productivity, comparing total agricultural output to the combined amount of land, labor, capital and intermediate inputs employed in production. The growth rate in TFP is estimated as the difference in the average growth rate in combined outputs and inputs. In other words, if total output is growing faster than total input, then each unit of output is being produced using fewer total inputs, and the average productivity of the inputs, or TFP, increases. Avila and Evenson (2010) found that for developing countries, average agricultural TFP accelerated from 1.39% per year during 1961–1980 to 2.31% per year during 1981–2001. Ludena et al. (2007), who's analysis covered the entire world, estimated

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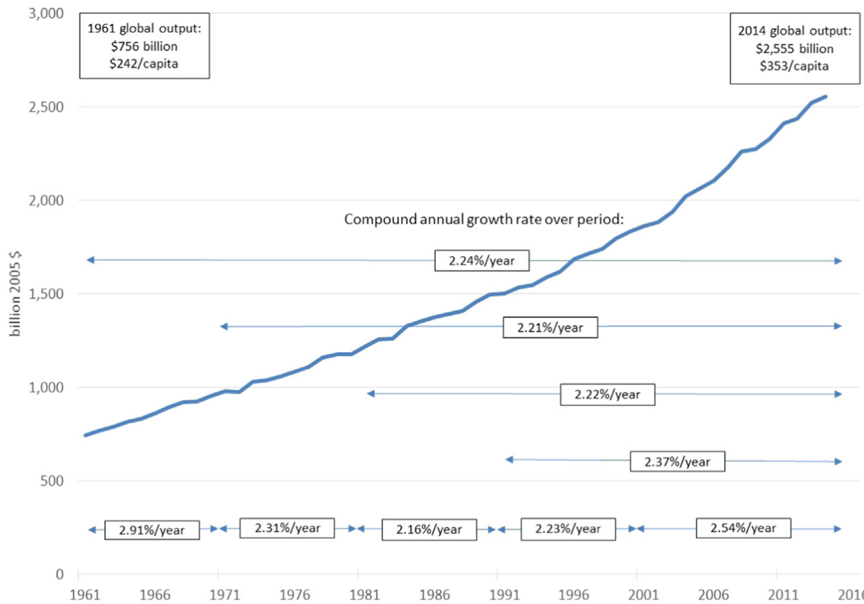

Fig. 1. World Agricultural Output, 1961–2014.
Source: Agricultural output is the sum of output of 187 crop and animal commodities valued in constant 2005 dollars (FAO, 2017). Population estimates are from the United Nations.

that annual average agricultural TFP grew from 0.60% to 1.29% per year over these same periods. Efforts to extend global agricultural TFP analysis beyond 2001 have been carried out by the U.S. Department of Agriculture's Economic Research Service (ERS). These estimates also show that global agricultural TFP accelerated in the 1990s and 2000s, compared with previous decades (Fuglie, 2015). However, estimating TFP requires reasonably complete information on prices and quantities of the whole set of agricultural inputs and outputs. FAO is the primary source of data used for international productivity assessments, but these series have some well-known deficiencies, particularly in labor and capital measures, and contain only limited information on prices. For this reason, Alston et al. (2010) caution against placing too much credence in global measures of agricultural TFP.

But perhaps the strongest evidence against a world-wide productivity slowdown is that the global rate of agricultural *output* growth has not slowed. Since 1961 the trend rate of growth in global agricultural output (the total of all crop and livestock commodities produced, aggregated by FAO using a constant set of global prices from 2004 to 2006), has shown no downward trend (Fig. 1). In fact, the growth rate in global agricultural output accelerated in recent decades. To maintain the hypothesis that productivity growth is slowing while output growth is not would necessarily imply that resources (land, labor, capital, etc.) employed in agriculture are expanding at an ever faster rate. While data on the use of resources in agriculture is mixed and of somewhat poor quality, the evidence does *not* suggest that there has been a major acceleration in the growth rate of inputs used in agriculture. In fact, of the two primary inputs used in agriculture (land and labor), the United Nations estimates that world-wide, the use of both have declined in absolute levels since the turn of the millennium. However, the use of capital and intermediate inputs such as fertilizers continue to increase (but not at an accelerated rate).

In this paper I revisit the question of the rate of productivity growth in agriculture.[1] I estimate growth rates for both single-factor (land and labor) productivity and total factor productivity for different regions (industrialized countries, developing countries, and developing countries excluding China) as well as for the world as a whole. This work uses the ERS international agricultural productivity accounts and also draws upon the newly revised estimates of agricultural labor from the International Labor Organization (ILO) and agricultural capital from FAO. The Supplement to this article also examines the sensitive of TFP to various measures of agricultural land. Using these alternative estimates of land, labor and capital, the evidence points toward accelerating, not slowing, productivity of single-factor and total-factor inputs in world and developing country agriculture.

2. Methodology

Analysis of agricultural productivity posits a production process in which output at time t (Y_t) is a function of inputs (X_t), a technology parameter (Λ_t) that measures the productivity of the inputs, and a random factor (E_t) that captures the effects of weather and other random or temporary shocks:

$$\boldsymbol{Y_t = f(X_t)\Lambda_t E_t}. \tag{1}$$

Output growth, or the rate of change in Y_t, is given by the derivative of Eq. (1) with respect to time. Letting small letters denote growth rates, output growth (y_t) is simply the sum of the growth in inputs (x_t), the growth in productivity of x_t given by λ_t, plus changes in the random factor:

$$\boldsymbol{y_t = x_t + \lambda_t + \varepsilon_t} \tag{2}$$

Due to the effects of random shocks such as weather, it may be hard to distinguish between trends in y_t, x_t, and λ_t and fluctuations around trend ε_t. Thus, assessments of productivity trends are usually based on comparing average growth rates in outputs and inputs over a decade or more. Trend growth in productivity of a resource X is then given by:

$$\overline{\lambda_t} = \overline{y_t} - \overline{x_t}, \tag{3}$$

where the bar above the variable signifies a multi-year moving average. In Eq. 3, $\overline{y_t}$ is the average annual growth rate in aggregate agricultural output (crop and animal commodities combined) while $\overline{x_t}$ is the average annual growth rate in either a single input (say land, to measure growth in land productivity), or a combination of inputs (say land, labor, capital, and intermediate inputs). The difference between them

[1] In this paper, agriculture is defined to include crops, livestock and related agricultural services, and exclude forestry and fishing. The corresponding ISIC code is A-01. Most of the analysis in this paper refers to the entire agricultural sector as defined here, although some analysis considers the crop and livestock sectors separately.