NJAS - Wageningen Journal of Life Sciences 77 (2016) 39–51

Contents lists available at ScienceDirect

NJAS - Wageningen Journal of Life Sciences

journal homepage: www.elsevier.com/locate/njas

Projections of long-term food security with R&D driven technical change—A CGE analysis

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ARTICLE INFO

Article history:
Received 1 September 2015
Received in revised form 11 March 2016
Accepted 11 March 2016
Available online 25 April 2016

Keywords:
Public agricultural R&amp
D investments
Land-augmenting technical change
Agricultural productivity
CGE model
Magnet
Food security

ABSTRACT

In this paper, the impact of public R&D investment on agricultural productivity and long-term food security via R&D driven endogenous technical change is analysed. The findings show that R&D growth rates at the level reached in 2000s, particularly those for China, would not be expected any longer. Concerning the impact of projected R&D investments on agricultural productivity, it is found that endogenous growth rates of land-augmenting technical change are comparably lower than the standard exogenous rates used in long term projections of agri-food markets. This suggests that public R&D investments are not able to stimulate agricultural production to the levels that would be expected from the standard baseline outcomes.

1. Introduction

There are various challenges for reaching long-term sustainable agricultural production and food security. On the one hand, there are increased demand pressures resulting from ongoing population growth, improving living standards in developing countries and increased demand from non-food sources such as biofuels and other sources of renewable energy. On the other hand, there are constraints at the production side, due to limited space for expansion of agricultural land, climate change and migration of rural labour to urban areas. Recently the FAO estimated that food production needs to be increased with 60 percent to feed the global population of 9 billion people in 2050. Around 80% of the projected growth will have to come from intensification, predominantly an increase in yields through better use of inputs (Alexandratos and Bruinsma, [1]). Increasing agricultural productivity and crop yield is becoming even more important considering the fact that land and water resources are becoming scarce, which makes extensive agriculture more and more problematic.

Agricultural R&D investments in biotechnologies such as GMO represent a possible solution, in addition to the diffusion of existing technologies, for the food security challenge, especially in developing countries where cereal yields are still well below the global average level. Continuous investments in R&D are important from the perspective of all food security dimensions (FAO, [2]). The *availability* dimension of food security is associated with the physical supply of food. According to various scholars (such as Avila and Evenson, [3], Fuglie, [4], Pardey et al. [5], Alston, [6]), investments in R&D are important drivers of agricultural productivity and food availability. As Pardey and Alston [7] point out, U.S. agricultural R&D has fuelled productivity growth and food supplies not only in U.S. agriculture but also globally via R&D and technology spillovers.

The *accessibility* dimension of food security looks at the economic determinants of the access to food such as households' income and the evolution and variability of food prices. Particularly for the poor, who spend around 50% of their income on food consumption, changes in the prices of mayor staple crops such as rice, wheat and maize, can have a dramatic impact. The positive occurrence of the period of low agricultural prices in 1980s-1990s was predominantly achieved by R&D investments in better seeds and varieties during the Green Revolution.

The *utilization* dimension of food security refers mostly to the population's ability to obtain sufficient nutritional intake. As

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http://dx.doi.org/10.1016/j.njas.2016.03.001

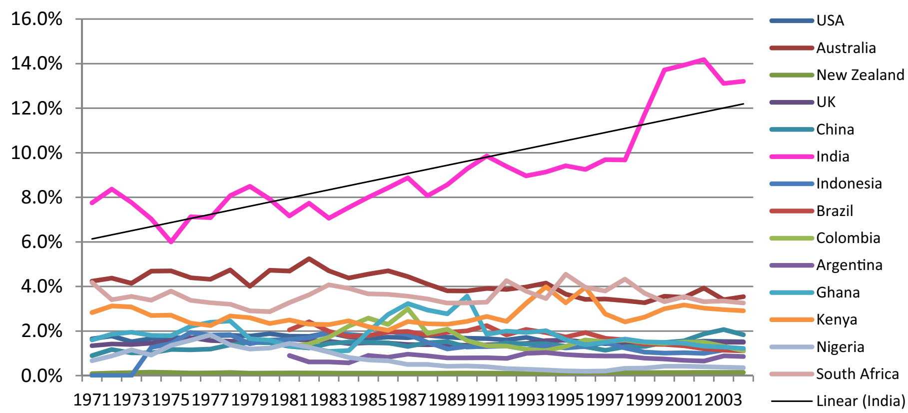

Fig. 1. Long-term evolution of the share of agricultural R&D expenditures in Gross Agricultural Output.
Note: R&D data compiled from various sources, data for Gross Agricultural Output taken from Fuglie dataset [4].

highlighted by Mogues et al. [8], the potential for agricultural investments to have significant and observable effects on health and nutrition is great. By increasing agricultural productivity, the corresponding farmer income gains can translate into better nutrition through greater calorie consumption and gains in dietary diversity, as well as improved health through a better ability to purchase medicine and access health services.

In view of this, the role of R&D investments as a key technology driver in achieving various dimensions of food security is undisputable. However, only limited attention is paid to R&D as a key technology driver in most of the leading assessment models that intend to project food security and corresponding changes in food production and prices. Recent work as part of the Agricultural Model Intercomparison and Improvement Project (AgMIP) has examined differences in long run food price developments into the future through systematic model intercomparison (Nelson et al. [9], [10] and von Lampe et al. [11]). Von Lampe et al. in the overview paper concluded that a vast area of uncertainty is the accounting of technical progress in agricultural production. Robinson et al. [12] show that assumptions differ widely among models and are another important driver behind the different results. They conclude that more empirical research is needed to open the black box of macro and sectoral technical change. As a result, the ability to guide policy makers in defining long-term food security strategies is weakened.

The objective of this paper is to provide projections of agricultural production, food prices and other food security indicators towards 2050 using a global CGE model with endogenous R&D driven technical change in agriculture. The R&D driven productivity developments obtained in these projections will be compared with established yield projections used in key global impact assessment models and analyses.

The contribution of this research is twofold: i) methodological, by incorporating a dynamic accumulation of R&D stocks including region specific time lags and their links to agricultural productivity in a state-of-the-art CGE model, ii) policy-oriented, by exploring the possible directions of R&D investments worldwide and their impacts on agricultural productivity and consequently on food security. The explicit inclusion of the R&D sector and corresponding R&D stock accumulation in this CGE model is a distinctive feature from all other global impact assessment models used in food security projections.

The paper is structured as follows: chapter 2 contains the literature review which served as a basis for incorporating public R&D investments in the CGE model, as described in chapter 3. In chapter 4, outcomes of the model are analysed and chapter 5 concludes.

2. Literature review

2.1. Public agricultural R&D investments—high returns but long lags

There is rich empirical evidence on the effects of R&D investments on productivity with generally significantly positive results. According to the meta-analysis of 289 studies conducted by Alston et al. [13], the average returns on R&D in agriculture reached 82% (mean) and 44% (median). Recently, Hurley et al. [14] re-examined the rates of return in 372 separate studies from 1958 to 2011 and confirmed the positive evidence of R&D investments, although with lower returns than previously advocated. Similarly, Mogues et al. [8] presented updated evidence from country case studies focused on developing countries. They conclude that literature on public investments strongly suggests that returns to research and extension are significant. Next to that they point out three observations – i) higher R&D returns are found in R&D for shorter production cycles, such as field crops ii) higher returns have been found in R&D in Asia and developed countries and iii) R&D is associated with higher returns than agricultural extension.

Although public R&D investments undisputedly bring large returns, their benefits accrue with considerable lags, contrary to industrial research, which has a more short-term experimental character.[2] Thus, specific approaches must be adopted that allow for alternative accumulation of R&D investments to reflect this delay in the construction of knowledge stocks in agriculture. Trapezoidal lag models, polynomial-distributed lagged forms (PDL) and gamma lag distributions are the most common and recommended forms for modelling R&D stocks in agriculture. Thirtle et al. [15] comment, that the gamma distribution is of interest since it offers the smooth form of a trapezoid, which can be estimated rather than imposed. By fitting knowledge stocks calculated from alternative distribution specifications in a TFP regression, Alston [6] found that in a double log function, a gamma distribution with a maximum 50-year lag and peak after 24 years yields the best result. For the

[2] As Alston et al. [4] explains research and development might take 5–10 years before the variety is adopted, due to time spent on experimental trials and regulatory approvals. After the variety is adopted, farmers have to learn how to produce it, and consumers have to accept the new product innovation on the market. Therefore, the peak of benefits only comes 15–25 years after the initial investment. Eventually, the variety may become obsolete, as it may be less effective against evolving pests or diseases.