ELSEVIER

Ecological Economics 38 (2001) 275–291

ECOLOGICAL ECONOMICS

www.elsevier.com/locate/ecolecon

ANALYSIS

Resource use and technological progress in agriculture: a dynamic general equilibrium analysis

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Received 5 September 2000; received in revised form 29 January 2001; accepted 30 January 2001

Abstract

We analyze the global effects of economic and population growth and the impact of a slowdown in agricultural total factor productivity (TFP) on agriculture and forest resources using a dynamic multi-region computable general equilibrium model with land use and cover detail. Given the current consensus about the growth of the world economy, our results suggest that food security will not be threatened and agricultural activities will not encroach on forest resources over the next decade. A slowdown in agricultural TFP growth might lead to higher crop prices in all regions, with South East Asia facing the steepest increases. A slowdown in agricultural TFP growth also might be accompanied by higher conversion rates of forestland to farmland as well as by greater environmental or ecological damages on the remaining forestland.

Keywords: Agricultural TFP growth; Population growth; Food security; Forestland

1. Introduction

The world's rate of population growth is slowing, but total population is still increasing at about 80 million per year, and is expected to reach 10 billion by the middle of the 21st century (World Bank, 1999). Most of this growth will take place in developing countries, particularly in Asia and Africa. These projected increases in population, along with growth in per-capita incomes and associated changes in demand for agricultural commodities, are expected to increase pressures on natural resources both through the expansion of land under cultivation and through more intense use of resources already employed in agricultural production. In support of these expectations, a recent study by Evenson et al. (1999) estimates that without the development of high yielding varieties of crops, prices for developing country consumers would likely be much higher than they are today. Technological ad-

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0921-8009/01/$ - see front matter
PII: S0921-8009(01)00165-3

vances in the cultivation of rice, for example, have reduced costly food imports by 8% and have eliminated the need to convert millions of hectares of forestland to agricultural uses as would have been required had yields remained at 1960 levels. This evidence highlights the central role of agricultural research in ensuring sustainable rural development and food security in high growth developing countries, and reducing the strain on forest ecosystems.

Research on technical advances in agriculture is abundant. Norton and Davis (1981), Alston (1993) provide exhaustive surveys of the literature on gains from agricultural research. Very few of the reviewed studies, however, examine the impacts of agricultural research in an international context and the effects of technological spillovers across regions. A more recent paper by Frisvold (1997) has filled in this gap in the literature by analyzing the open economy aspects of agricultural research in a multi-region general equilibrium context with the Global Trade Analysis Project (GTAP) model (Hertel, 1997). The paper nicely illustrates how international spillovers are important aspects of agricultural research. It also extends the analysis of spillovers in a single commodity, single stage of production setting (Edwards and Freebairn, 1984) by considering the full multi-region, general equilibrium implications of such spillovers. The methodology adopted by Frisvold overcomes two of the limiting assumptions of the single-commodity, partial equilibrium models used by most returns-to-research studies, namely, that prices and production of all other commodities are fixed, and that research results from one region do not affect the productivity in others. The methodology does not, however, account for the dynamic effects of economic and population growth or calculate land-use changes between the agricultural sector and the rest of the economy.

The methodology used by Frisvold was extended by Darwin et al. (1995, 1996) in the Future Agricultural Resources Model (FARM) to include the competition for land among agriculture, forestry, and all other sectors in the economy. The methodology was also extended by Ianchovichina and McDougall (2000) to include a dynamic theory of asset ownership and investment. These two extensions are combined in a dynamic version of FARM (D-FARM), which we use to examine how agricultural total factor productivity (TFP) interacts with forestland use and timber harvest rates.

Our results support the findings by Evenson et al., 1999) that a slowdown in agricultural TFP will raise world prices and lower world production of agricultural commodities while expanding farmland usage. This expansion in demand for farmland leads to permanent conversion of forestland into farmland and increases the environmental threat from deforestation. The loss in productivity in agriculture affects welfare in all regions negatively, with the bulk of the problems faced by regions in which agriculture accounts for a higher share of the gross domestic product.

The paper is structured as follows. Section 2 describes the modeling framework and solution procedure, and discusses the data and parameters. Section 3 discusses the design of and the results from the baseline simulation. Section 4 focuses on the effects of a slowdown in agricultural TFP with spillover effects. We summarize the major findings of the study in Section 5.

2. Methodology

This research uses D-FARM to estimate how TFP interacts with forestland use and timber harvest rates during the period from 2000 to 2007. This section briefly describes D-FARM's structure, outlines the solution procedure, and discusses the data and parameters.

2.1. The modeling framework

D-FARM, an extension of GTAP (Hertel, 1997), is a global, multi-commodity, applied general equilibrium (AGE) model with 12 regions and 18 commodities, 11 of which are agriculture-related products (Table 1). D-FARM incorporates global production, consumption, trade and policy distortions and offers a systematic way for determining the likely pattern of changes in factor and commodity prices, and production around