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Science for food, climate protection and welfare: An economic analysis of plant breeding research in Germany

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ABSTRACT

We analyze the economic effects of plant breeding research in Germany. In addition to market effects, for the first time also effects of reduced CO_2 emissions due to productivity increases are being quantified. The analysis shows that investments in German plant breeding research in the period 1991–2010 have reduced the global expansion of agricultural area by 1–1.5 million hectares. This has led to reduced CO_2 emissions of 160–235 million tons. The economic value generated by plant breeding research, through increased production and reduced greenhouse gas emissions, is estimated at 10.8–15.6 billion EUR in the same period. This can be translated into a social rate of return on research investment in the range of 40–80% per year. Projections for the period 2011–2030 generate a return rate in the range of 65–140% per year. Investments into plant breeding research in Germany are highly profitable from a societal point of view. At the same time, our results show significant under-investments in agricultural research in Germany. These results provide a good justification for policy-makers to reverse funding cuts for public agricultural research over the last decades and to improve institutional conditions for private research, e.g. through better protection of intellectual property rights.

1. Introduction

The economic conditions for world agriculture have changed dramatically. This also holds true for agriculture in the European Union. The secular trend of falling agricultural prices (i.e. adjusted for inflation) has come to an end. Since the turn of the millennium the prices for major agricultural commodities have steadily increased. This development is expected to continue, as global demand for agricultural products is rising faster than supply. Main reasons are rapid growth of population and income in many developing and emerging economies.

In the first half of the 21st century global food demand will double. Rising demand can be fulfilled either by expanding agricultural land or raising agricultural productivity. The first option is limited, as suitable areas for agricultural expansion are scarce. The most productive areas are already in use. In many parts of the world there are hardly any unused agricultural land reserves which could be mobilized. Some available areas, like tropical forests or savannas, should rather not be used for reasons of biodiversity conservation or climate protection.

Over the last 50 years, the largest contribution to growth in world agricultural output was due to productivity growth. This accounted for about 80% of additional output, while only about 20% was due to area expansion (FAO, 2010). In the future, global agriculture has to rely even more on increasing productivity, if growing demand from a rising world population is to be met (FAO, 2009). Without immediate and decisive action, the required productivity growth will not be achieved. Since the second Green Revolution in the 1960s and 1970s, global agricultural productivity growth has slowed down. Between 1960 and 1990 agricultural productivity grew by about 4% per year. It has now fallen to 1% per year. In the European Union growth rates are even lower, at about 0.6% per year (von Witzke and Noleppa, 2010). Public policies for pollution reduction within the EU may also have an effect on agricultural productivity, depending on specific regional circumstances (Falavigna et al., 2013).

One major reason for reduced technological progress is reduced investments in agricultural research and development (R&D). Under conditions of excess supply in the EU, North America and elsewhere, public investments in agricultural research activities have been scaled down. This has been particularly true for investments which are specifically aiming at productivity increases (Alston et al., 2010; Pardey, 2009). Neglecting agricultural research is one of the major reasons, why the EU has become the world's biggest net importer for agricultural commodities. The land area, which the EU

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uses outside its territory for fulfilling domestic demand, meanwhile amounts to more than 30 million ha, i.e. an area comparable to the size of Germany (von Witzke and Noleppa, 2010).

The majority of poor countries in the world used to be net exporters of food in the trade relationships with rich, industrialized countries. Now many of them are net importers of food. The import gap of poor countries will increase fivefold by 2030, compared to the year 2000 (FAO, 2003). Even under the best of a range of plausible projections, most poor countries will not be able to fulfill their quickly growing demand from domestic production over the coming decades. Their fast growing import gap can only be filled, if the rich countries also produce more and export agricultural commodities.

Moreover, growing EU net imports also have environmental consequences, as additional agricultural areas in other parts of the world are taken into production. Following Searchinger et al. (2008), the phenomenon of shifting production to other world regions has been labeled "indirect land use change" (iLUC). Large amounts of carbon dioxide (CO_2) are released into the atmosphere due to tropical deforestation and conversion of forest and grass land into cropland. Expansion of agricultural areas contributes more to global anthropogenic greenhouse gas emissions than industry or transportation (e.g. IPCC, 2014; Stern, 2007). Agricultural innovation and related productivity increases, also in rich countries like Germany, play an important role for global food security as well as reduction of CO_2 emissions. In this context, plant breeding research is crucial. Recent research has shown that the share of plant breeding and plant-genetic improvements in total productivity growth in agriculture has increased over time (e.g. Ahlemeyer and Friedt, 2010; Mackay et al., 2009; Webb, 2010).

In this paper, we conduct a classical cost–benefit analysis of plant breeding research in Germany, including direct market effects as well as reductions in CO_2 emissions due to indirect land use changes. We make use of a unique primary data set on research expenditures by private breeding enterprises in Germany. Changes in consumer and producer welfare due to productivity increases are quantified and compared to investments into research and development. Thus, overall welfare changes for society can be derived, also including the monetary benefits from reduced greenhouse gas emissions.

In the next section, we present our methodological approach. Section 3 provides an overview of data sources for calculation of productivity changes and agricultural research investments in Germany. In Section 4 we present results of the analysis, followed by a discussion. Based on our quantitative results, conclusions are drawn with a focus on implications for national and international research policy.

2. Theoretical basis and methods

The starting point of our analysis is the change in total factor productivity (TFP) per hectare (ha) in agriculture. This indicates which part of observed changes in land productivity is caused by genuine innovation, and cannot be related to increased factor use intensity:

$$dTFP/TFP = dQ/Q - (dI/I) * SI - (dL/L) * SL \quad (1)$$

with: Q = Index of production, I = Index of all intermediate inputs used (e.g. fertilizer, pesticides, machinery), L = Index of labor input, S = Expenditure shares of specific production factors.

Changes in TFP growth can then be used in a market modeling framework to assess social welfare changes. The conceptual approach of this analysis is shown in Figs. 1 and 2 for the simplest case of an agricultural sector without international trade. Figure 1 shows a typical market diagram, where the demand function of consumers (D) represents the willingness-to-pay for alternative quantities of good Q. The total willingness to pay for the amount Q1 is the area under the demand function between the origin and Q1. As a matter of fact, consumers only pay the market equilibrium price P1 for the total amount Q1, i.e. the rectangle P1 * Q1. The difference between the willingness-to-pay of consumers and what they really pay is the triangle between the demand function and P1 (also called "consumer surplus").

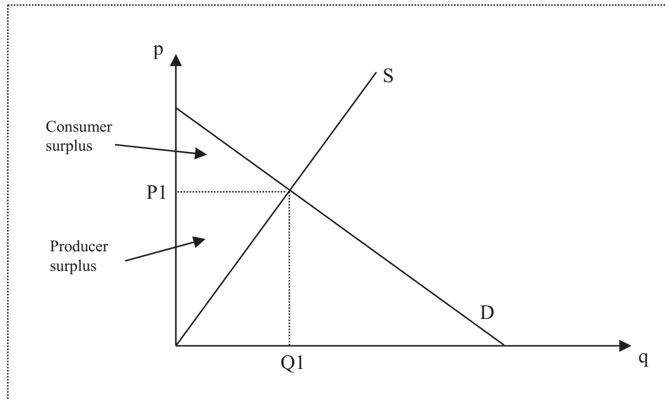

Fig. 1. The economic effects of a market exchange for farmers, consumers and society.

The supply function (S) is determined by the marginal costs of production. The total (variable) costs of quantity Q1 supplied to the market are given by the area below the supply function between the origin and Q1. As a matter of fact, total revenue by farmers is equal to total expenditure by consumers, i.e. the rectangle P1 * Q1. The triangle between market price and supply curve represents the economic value which accrues to the farmers through the market exchange (also called "producer surplus"). Total utility of society, or "social welfare", can be calculated in this simplified approach by the sum of consumer and producer surplus.

The gain in social welfare, which arises from an increase in productivity, is shown in Fig. 2. An increase in productivity leads to falling production costs and, hence, to a shift of the supply function to the right, from S to S'. As a consequence, the equilibrium quantity increases to Q2, while the price falls to P2. Social welfare rises by the shaded area.

For the quantitative analysis in this paper, the social welfare effects have been derived with a multi-market partial equilibrium model. The model has been described in detail in von Witzke and Noleppa (2010) and Jechlitschka et al. (2007). The model covers the following regions: Germany, Rest of EU, North America, South America, Asia, Oceania, Rest of the World. The following commodities are included in the analysis: wheat, corn, coarse grains, rice, soybeans,

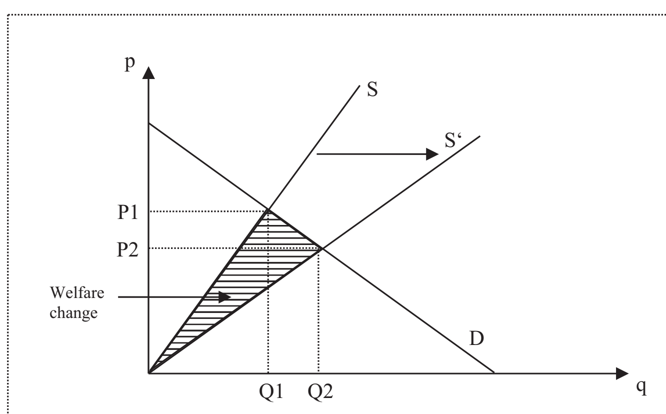

Fig. 2. The increase in utility for farmers, consumers and society, due to an increase in productivity.