# Social rate of return to plant breeding research in Germany

# Die gesamtwirtschaftliche Verzinsung der Pflanzenzüchtungsforschung in Deutschland

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## Abstract

**This article focuses on the social rate of return to plant breeding investment in Germany between 1980-2000. Starting point of the analysis is the development of total factor productivity which is decomposed into the effects of factor input and research investment. Information on investment in plant breeding have been obtained via questionnaires sent to both private plant breeding companies and public research organizations. The empirical results suggest significant underinvestment in German plant breeding research, as the calculated social rate of return is in the range of 16 to 28%.**

## Key words

**agricultural research; plant breeding investment; social rate of return**

## Zusammenfassung

**Gegenstand der Untersuchung ist die gesamtwirtschaftliche Profitabilität der Pflanzenzüchtungsforschung in Deutschland. Ausgangspunkt der Analyse ist die Entwicklung der totalen Faktorproduktivität in Deutschland. Diese wurde mit Hilfe eines Indexzahlenansatzes dekomponiert in die Einflüsse von Faktoreinsatzveränderungen und Investitionen in die Forschung. Informationen über die Investitionen in die Pflanzenzüchtungsforschung wurden durch Befragungen privater Pflanzenzüchtungsunternehmen und Einrichtungen der öffentlichen Pflanzenzüchtungsforschung gewonnen.**

**Die empirische Analyse für Investitionen im Zeitraum von 1980 bis 2000 ergab eine jährliche gesamtwirtschaftliche Verzinsung von 16 % bis 28 %. Damit liegt die gesamtwirtschaftliche Verzinsung deutlich über den Opportunitätskosten der Forschungsaufwendungen. Aus gesamtwirtschaftlicher Sicht wird daher in Deutschland in die Pflanzenzüchtung unterinvestiert.**

## Schlüsselwörter

**Agrarforschung; Pflanzenzüchtung; gesamtwirtschaftliche Verzinsung**

## 1. Introduction

Plant breeding is a fairly sizeable agricultural industry in Germany. As in other countries, it has generated remarkable gains in farm productivity. The objective of this article is to determine the social profitability of plant breeding investment in Germany.

The analysis of the social rate of return to agricultural research has a long tradition (e.g. Ruttan, 1982; ALSTON et al., 1995; ZIMMERMANN and ZEDDIES, 2000). Typically, the social rate of return reported in the literature is in the range of 40-60%, sometimes even higher. A key critique of these results is that the analyses usually relate the productivity gains of agricultural research to the investment in public agricultural research only, while neglecting private research investment. This is due to insufficient information on agricultural research by the private sector. As a consequence, analyses typically have overestimated significantly the order of magnitude of the social rate of return to investment in agricultural research (FOX, 1985).

The analysis presented in this paper is based on information about both private and public sector investment in plant breeding. Therefore, we have been able to avoid this upward bias in our results.

## 2. Methodology

There are a considerable number of approaches that can be and have been used in the analysis of the social rate of return to research. Their pros and cons have been discussed in great detail by ALSTON et al. (1995). One type of approach is based on econometric methods. Usually, a specification such as the following has been used:

(1) $Q_t = f(X_t, Z_t, T_t, U_t)$

where

(2) $T_t = g(R_t, \ldots\ldots, R_{t-n})$

$Q$ = quantity produced
$X$ = vector of conventional production factors (land, labor, capital etc.)
$Z$ = vector of pubic goods
$T$ = technology
$U$ = random variable
$R$ = research investment
$t$ = time index.

In principle, this system of equations could be estimated. Alternatively, a dual approach could be used by estimating indirect cost functions. A key problem with econometric methods in the analysis of the social rate of return to research is that problems of multi-collinearity are often difficult to overcome. Therefore, in this paper an index number approach has been used.

The starting point of the analysis is the total factor productivity:

(3) $TFP_t = Q_t / X_t$

$Q$ = aggregate production

$X$ = aggregate factor input.

The change in total factor productivity is:

(4) $tfp_t = q_t - x_t$

$tfp = dTFP / TFP$

$q = dQ / Q$

$x = dX / X$.

The change in total factor productivity is considered to be the result of investment in research. The focus of this analysis is investment in plant breeding. Therefore, in the empirical analysis, the productivity effect of plant breeding has to be separated from that of other agricultural research investment. In order to account for changes in total factor productivity due to weather and other random variables, average changes over several years have been used.

## 3. Data

The analysis for Germany is based on plant breeding investment during the time period 1980 through 2000. For 1980-1991 former West Germany has been considered, while for 1992-2000 data for unified Germany has been used. The total factor productivity and its rate of change have been calculated using publicly available federal data sets from the Economic Accounts for Agriculture.

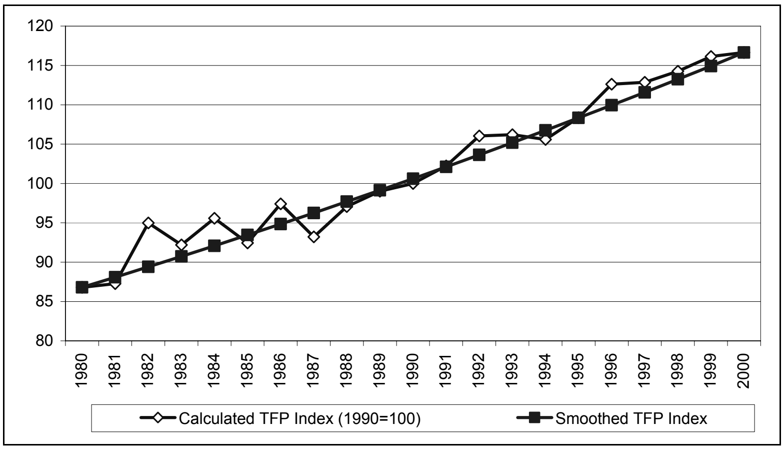
We have derived separate volume indices for total output, aggregate use of intermediate inputs, and labor input. These volume indices have then been combined into an index of total factor productivity. In the output index, we deliberately included livestock production in order to account for spillover-effects from plant breeding such as increased feed production or improved feed quality.

While the volume indices for total output and intermediate inputs have not changed much over time, labor input has declined sharply in the last two decades. Contrary to our expectation, German unification did not have a discernible impact on total factor productivity growth. Figure 1 depicts the evolution of the TFP.

A key parameter in this analysis is the share of growth in total factor productivity which can be attributed to plant breeding. In the literature (FRIEDT, 2001; GEPTS, 2003; ISF, 2002) this number is reported to be in the range of 30% to 50%. In the empirical analysis, 40% was used with a parameter variation of 30% and 50%.

Data on expenditures related to plant breeding research have been collected by means of two surveys. Information on private plant breeding investment were calculated from a questionnaire sent to about 50 members of the German Association of Plant Breeders (BDP). The aggregated results could be used directly in our calculations. Public investment was calculated using information provided by the major public research institutions in the field, including university plant breeding departments. In the public sector, some adjustments had to be made in order to separate investment in basic research from applied research which contributes directly to productivity changes. Based on additional evidence from the literature, we obtained a plausible order of magnitude for the ratio of public to private investment in plant breeding. In the empirical analysis, the ratio used was 62.5% with a parameter variation of 50% and 75%.[1]

**Figure 1. Total factor productivity in German agriculture, 1980-2000 (1990=100)**




Source: own calculations

## 4. Market and welfare effects

The social welfare effects of a gain in productivity can be illustrated graphically.[2] Figure 2 depicts the market for a good Q in a large importing country under free-trade. Agricultural research raises total factor productivity which, in turn, acts to shift the supply curve to the right. Therefore, the price declines. The shift of the supply curve acts to increase producer surplus, all other things being equal. The price decline results in consumers gaining more than producers lose. As a consequence, the net change in social welfare is positive. In figure 2, the social welfare gain is represented by the shaded area.

During the time period analyzed here, the European Union's Common Agricultural Policy has provided substantial producer price support. This somewhat complicates the graphical exposition of the social welfare effects. In essence, this acts to reduce the social welfare gain of agricultural research, as long as the domestic support price does not decline in response to the supply growth induced by research. This scenario is depicted in figure 3 for the case of imports under the threshold price/ variable import levy system in a large country. The case of exports under the export restitution system can be analyzed analogously. Again, it has been assumed that there are no international spillovers of domestic research.

The starting point of the analysis is the equilibrium under the variable levy system. The price which prevails domestically is $P_s$ while the world market price is denoted by $P_w$. Agricultural research acts to shift the supply function to S'.

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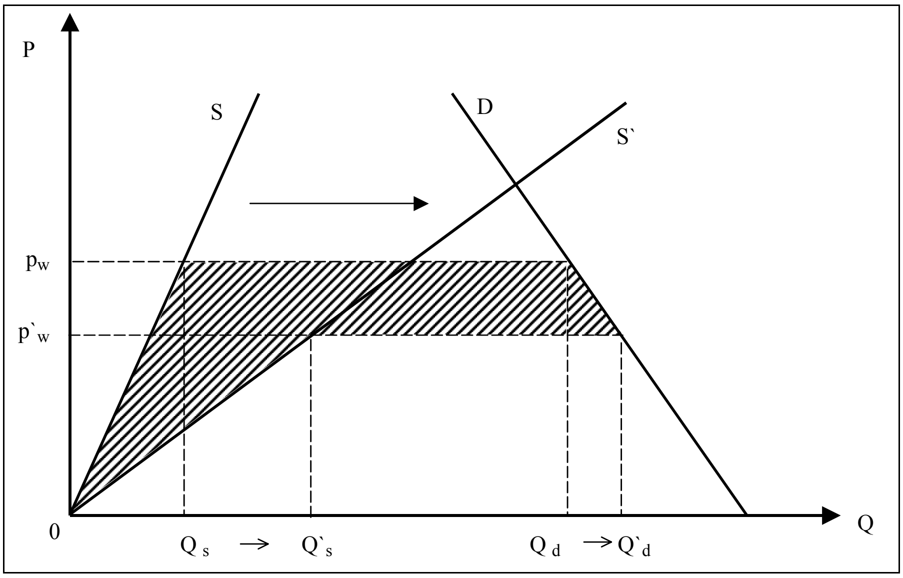
1 For details see VON WITZKE et al. (2004).

2 ALSTON et al. (1995) have analyzed the social welfare effects of agricultural research for a wide range of scenarios.

**Figure 2. Social welfare effects of agricultural research in a large importing country (no technology spillover)***

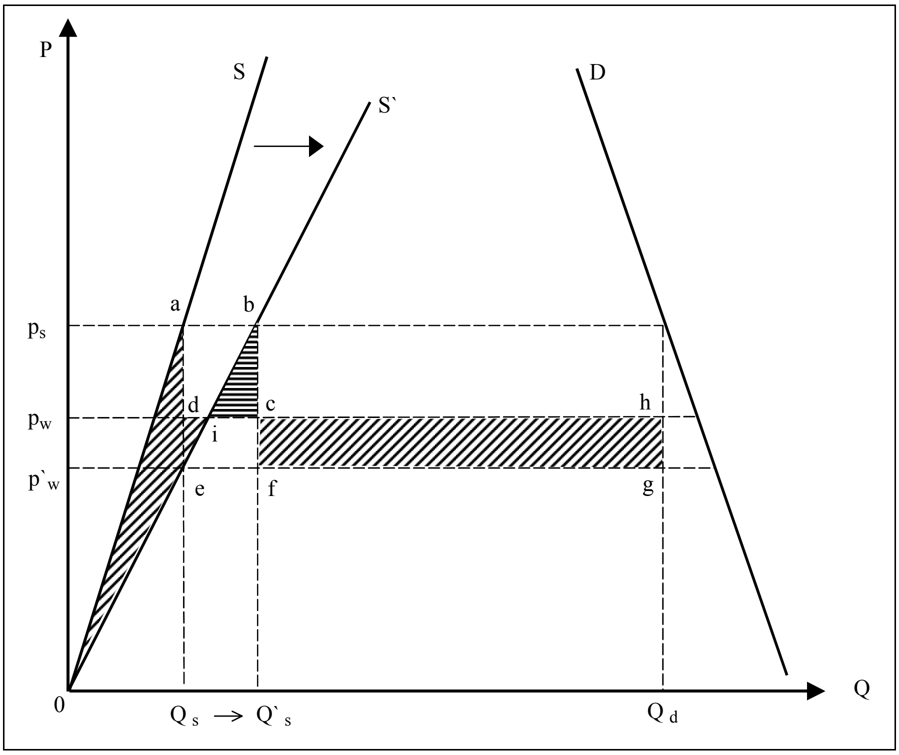



* The assumption of no policy spillovers implies that German plant breeding investment does not affect foreign productivity and, vice versa, that foreign plant breeding does not affect domestic productivity.

Source: own illustration

As a consequence, domestic production increases to $Q_s$'. As the domestic price remains constant, consumer surplus does not change and the gain in producer surplus is the area 0 a b. The decline in the world market price leads to an increase in the variable levy per unit imported. The new quantity imported declines to $Q_d$ - $Q_s$'. Therefore, the gain in government revenue is c h g f minus a b c d. The resulting gain in social welfare is the area shaded diagonally minus the triangle b c i which is shaded horizontally.

**Figure 3. Social welfare gains of research in a large importing country with a minimum export price (no international spillovers of research benefits)**




Source: own illustration

## 5. Empirical analysis

Research investments typically result in benefits with a time lag and then provide benefits for more than one period. In our analysis, we have considered a continuous stream of welfare benefits due to research over a period of 20 years. We neglect the impacts of research before and beyond the time period considered, assuming those effects to be identical.

Our approach is illustrated graphically in figure 4. In the empirical analysis, the parameters for the shift in the supply function have to be determined. For this purpose, a Cobb-Douglas type isoelastic supply function has been used.

(5) $Q_t^s(P) = c\,(1+f_o)\cdot\ldots\cdot(1+f_n)\,(P_n)^{\varepsilon^s}; \quad \varepsilon^s > 0$

$Q_t$ = quantity supplied

P = market price

c = supply function parameter

f = supply function shift parameter

$\varepsilon^s$ = supply elasticity.

As research does not affect the demand function:

(6) $Q_t^d\,(p) = d\,p^{\varepsilon^d} \quad ; \quad \varepsilon^d < 0$

$Q_t^d = Q^d$ = quantity demanded

d = demand function parameter

$\varepsilon^d$ = demand elasticity.

The first step in the process of determining the social rate of return to plant breeding in Germany is to calculate for each period t the difference between social welfare gain and investment in plant breeding.

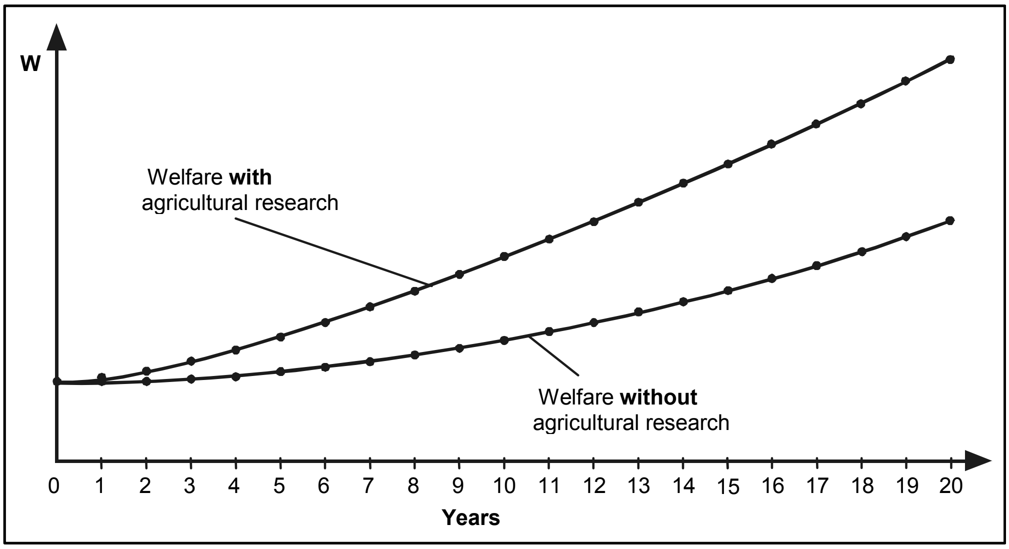
(7) $NW_t = GSW_t - IPB_t$

NW = net welfare gain of plant breeding

GSW = gain in social welfare resulting in plant breeding investment

IPB = Investment in plant breeding.

**Figure 4. Effects of agricultural research and plant breeding over time**




Source: own illustration

As can be seen, the results are fairly robust. Even in the worst case scenario the social rate of return remains positive, while in the best case scenario the social rate of return is in the range usually reported in the literature.

## 6. Conclusion

As has been shown in this paper, the social rate of return to plant breeding in Germany is high. It is somewhat lower than most of the results reported in the literature. This has been expected, however, as most analyses had to neglect the investment in private plant breeding, thus overestimating the rates of return.

Our results establish a lower bound for the social rate of return to plant breeding for several reasons. First, international research spillovers have not been considered. That is, the benefits of domestic plant breeding exported to other countries have not been accounted for. Second, the world price effects resulting from plant breeding induced supply growth in Germany have been assumed to be zero. Although the effect of a change in Germany's supply of crops on the world market prices might be fairly small, the social welfare effect could be quite sizable because the small price change would effect a large quantity.

Then, the social rate of return to plant breeding (RS) can be determined as:

$$(8)\quad \sum_{t=o}^{n} \frac{1}{(1+\mathrm{RS})^{t}} \cdot \mathrm{NW}_t = 0$$

The results of the empirical analysis are summarized in table 1. Social rates of return have been calculated for investment in 1980-1991 and 1992-2000. They turn out to be high by any standard, although they are somewhat lower than most analyses reported in the literature (e.g. HAYAMI and RUTTAN, 1985). This had been expected, however. As discussed earlier, the vast majority of analyses have related total research benefits only to public investment in research (FOX, 1985), thus overestimating the social profitability of agricultural research.

**Table 1. The social rate of return to plant breeding investment in Germany, 1980-1991 and 1992-2000**

| | time period | |
|---|---|---|
| | 1980-1991 | 1992-2000 |
| social rate of return (%) | 28 | 16 |

Source: own computations

As mentioned above, two parameters in our analysis are somewhat critical because they could not be determined directly and had to be based in part on evidence from the pertinent literature. One is the ratio of public to private plant breeding investment. The data on private sector plant breeding investment was unambiguous. However, in some public plant breeding departments, equipment and other resources are used for both basic research and plant breeding research. The other variable is the share of plant breeding research in the growth of total factor productivity. For both parameters a sensitivity analysis was done. The results are exhibited in table 2.

**Table 2. Sensitivity analysis of results in table 1**

**Table 2a. Investment in 1980-1991**

| | | Share of plant breeding in total productivity growth (%) | | |
|---|---|---|---|---|
| | | 30 | 40 | 50 |
| Proportion of public to | 50 | 17 | 33 | 48 |
| private plant breeding | 62,5 | 13 | **28** | 42 |
| investment (%) | 75 | 9 | 13 | 37 |

**Table 2b. Investment in 1992-2000**

| | | Share of plant breeding in total productivity growth (%) | | |
|---|---|---|---|---|
| | | 30 | 40 | 50 |
| Proportion of public to | 50 | 10 | 18 | 25 |
| private plant breeding | 62,5 | 8 | **16** | 23 |
| investment (%) | 75 | 6 | 14 | 20 |

Source: own computations

Third, plant breeding has an immediate impact on the environment. Plant breeding raises land productivity. Thus, a given volume of production can be realized with a smaller acreage for food production. This, in turn, results in a reduction of natural habitats being transformed into farmland.

Finally, it must be noted that plant breeding acts to reduce malnutrition and premature death. The reason is obviously that plant breeding results in more food at lower prices. The social welfare effects of the reduction in malnutrition can be quantitatively determined in principle. Typically, they are not included in analyses of the social rate of return to agricultural research because of a lack of suitable data, however.

The results reported in this paper support RUTTAN's (1980) under-investment hypothesis for plant breeding in Germany. As the social rate of return is significantly above the opportunity cost, i.e., the long term real interest rate, social welfare would increase with increasing research investment. The sad and paradoxical situation in Germany and in all too many other developed countries is that public agricultural research investments are being reduced rather than expanded.

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