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Agricultural Economics 21 (1999) 231–239

AGRICULTURAL ECONOMICS

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Redistribution of social benefits from advances in extension and research in the Tanzanian maize industry

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Received 19 February 1999; accepted 24 June 1999

Abstract

This study determined consumer and producer welfare gains from advances in extension and research in the maize industry of Tanzania to determine how a national taxing schedule should be determined. It was found that, for an off-farm marketable surplus of 40%, consumers and producers gain equally, while for an off-farm marketable surplus of 60%, consumers realize 75% of the welfare benefits. This suggests that consumers and producers should share equally in a revenue generating tax for funding maize research and extension programs. However, for large producers with a marketable surplus of 60% or more, their tax should decrease proportionally to the amount sold. Alternatively, if taxed equally, large-scale producers should receive some form of compensation through direct government payments. ©1999 Elsevier Science B.V. All rights reserved.

Keywords: Welfare analysis; Taxing incidence; Low income countries

1. Introduction

Subsistence food crops are common to low income countries (LICs) and their dependency on these crops has been well documented (e.g., Staub and Blase, 1974; Toquero et al., 1974; Hayami and Herdt, 1977; Behrman and Murty, 1985). Increased productivity of staple food crops in LICs has come from research and extension efforts to educate producers (Pingali and Rosegrant, 1998; Traxler and Byerlee, 1992). In Tanzania, a National Maize Research Program (NMRP) was formed to develop maize production technologies and to educate producers through extension efforts. However, the NMRP, as other research and extension programs in Tanzania and LICs in general, has been experiencing financial difficulties. Tanzania has been implementing monetary and fiscal reforms that have led to reduction in research and extension funding. Additionally, as Norman (1991) noted, there has been a decline in donor support for research in LICs. For continued existence of the Tanzanian NMRP, it will be necessary for producers and consumers to bear an increasing amount of the costs required to continue maize research. This analysis seeks to determine the distribution of social benefits from extension and research in the Tanzanian maize industry so that inferences can be made on how the costs of continuing the NMRP should be distributed among consumers and producers.

The Tanzanian economy is dependent on the agricultural sector, which approximately 90% of Tanzania's 28 million inhabitants are employed by or di-

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0169-5150/99/$ – see front matter
PII: S0169-5150(99)00029-8

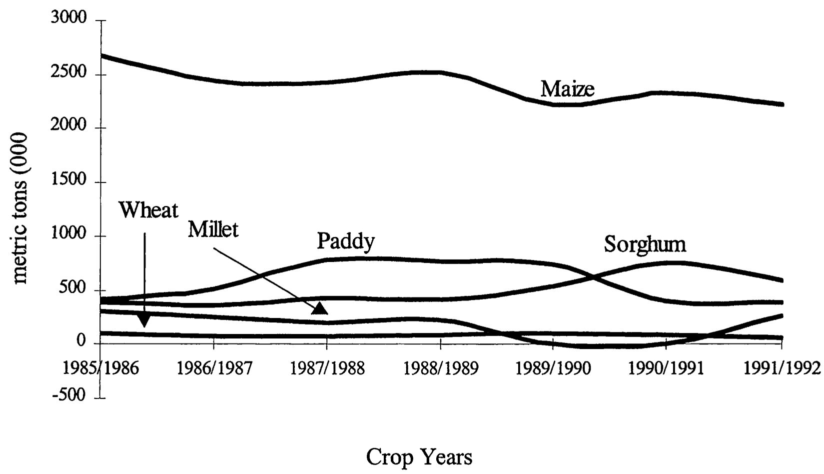


Fig. 1. Annual production of Tanzanian cereal crops (1985–1986 through 1991–1992).

rectly dependent on. Small farmers, with acreage of less than 3 ha, account for 85% of total agricultural output. The agricultural sector generates 85% of total export earnings (Missiaen and Lindert, 1993; Moshi et al., 1997). Though the country retains a negative balance of payments in most years, Tanzania is consistently a net agricultural exporter.

Maize is Tanzania's most important staple food crop (Fig. 1) and the most common crop produced by the small-scale farmers (Moshi et al., 1997). Tanzanian maize production accounts for 60% of cereal crop acreage (1.7 million hectares). The Tanzanian per capita consumption of maize is one of the highest in the world at 100 kg per person a year. Maize consumption in Tanzania provides 70% of the energy and 50% of the protein requirements for the 28 million inhabitants (Kirkby, 1994; Moshi et al., 1997).

Numerous previous studies have investigated social welfare benefits associated with introducing new technology/knowledge into the production process of agricultural commodities (e.g., Schmitz and Seckler, 1970; Ayer and Schuh, 1972; Akino and Hayami, 1977; Latimer and Paarlberg, 1978; Lindner and Jarrett, 1978; Fuglie, 1995). However, only a few studies have examined assessing a research tax incidence dependent upon the welfare distribution of research benefits. In investigating the impact on the US corn yields from investment in extension and research, Griliches (1958) examined the accessing of a taxing schedule dependent upon the distribution of welfare benefits from improved corn production. Like the case of changes in corn yield due to the introduction of new varieties in the US for Grilliches' study, a similar change in maize yields has occurred in the Tanzanian maize production (Fig. 2).

The distribution of social benefits from extension and research between consumers and producers is heavily influenced by the price elasticity of demand for agricultural products. The distribution also depends on elasticity of supply and the nature of the supply shift caused by the adoption of improved production methods. In the case where demand for an agricultural product is price elastic, farmers would benefit more from research. In this case, farmers would be willing to pay a research tax, e.g., the case of the Malaysian rubber producer (Stevens and Jabara, 1988). However, if the demand for an agricultural product is price inelastic, its price may be high and a production increase due to extension and research would benefit consumers more than producers. Consumers, in this case, would be more willing to fund extension and research. This situation is common in high income countries where the elasticity of demand for food crops is more inelastic than for the case of LICs (Stevens and Jabara, 1988). In LICs, cereals are a staple to the majority. Thus, these crops are associated with price inelastic demand since farmers in LICs retain a large portion of their produce. In this case, the benefits of research are ambiguous when using standard welfare formulations.

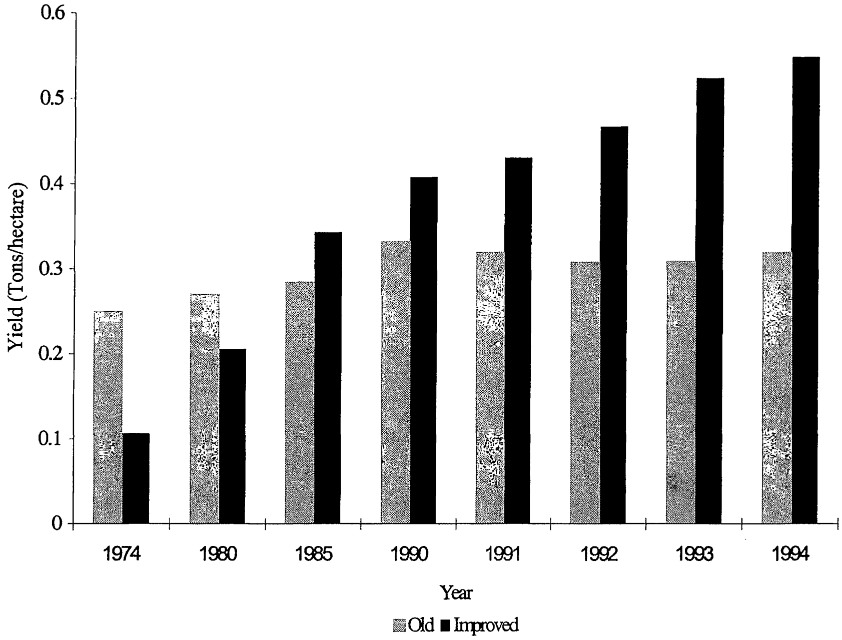


Fig. 2. Annual yields of old and improved Tanzanian maize cultivars (1974 through 1994).

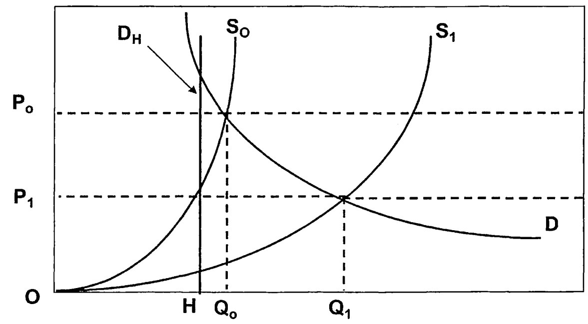
This study uses the Tanzanian farm maize production survey data to calculate the rate of shift in supply from advances in extension and research, rate of adoption of new seed varieties, and percentage of off-farm marketable surplus to evaluate consumer and producer welfare benefits from advances in extension and research. Using this information, welfare analysis is used to determine who benefits more between producers and consumers due to increased maize production from advances in extension and research. This information is needed to determine whether Tanzanian consumers or producer should bear a greater proportion of the extension and research costs of producing maize.

2. Methodology

The goal of any producer in a market economy, whether in a high income country or an LIC, is to maximize profits. LICs differ from high income countries only in the amount of marketable product available to maximize profits. In LICs, much of the crop is consumed on-farm in the maximization of producer utility. Hayami and Herdt (1977) provided methods for computing the distribution of extension and research benefits of staple crops grown by subsistence farmers in LICs. As Tanzania is classified as an LIC, this procedure is followed for evaluating the distribution of social benefits to Tanzanian consumers and producers. Fig. 3 illustrates how differences in relative levels of consumer and producer benefits arise between low and high income countries. This effect is distinguishable by the rightward shift in the vertical axis (O to H) for the case of producers consuming a large portion of the crop on-farm. Thus, for LICs, a rightward shift in supply due to technological advances has a far more different impact on the change in the distribution of welfare benefits than for a high income country. For a complete discussion of differences in consumer and producer benefits between high income countries and LICs, see Hayami and Herdt (1977).

Assume that producers in LICs consume a specific amount on-farm (h) and the remainder ($r=(1-h)$) of the crop is marketable. Equilibrium conditions for determining profit maximizing quantity levels in an LIC can be specified as (Akino and Hayami, 1975; Hayami and Herdt, 1977)

$$Q_S = (1-h)\, f(P, \boldsymbol{X_S}) \tag{1}$$



O is the origin when primary consumption occurs off-farm as in high income countries.
H is the origin when primary consumption occurs on-farm as in low income countries.
D represents the demand curve for marketable surplus.
D_H represents the demand curve for on-farm consumption.
S_o represents the supply curve prior to advances in technology due to extension and research
S_1 represents the supply curve after advances in technology due to extension and research
P_o represents the equilibrium price prior to advances in technology due to extension and research
P_1 represents the equilibrium price after advances in technology due to extension and research

Fig. 3. Shift in supply form a change in extension and research for an LIC.

$$Q_D = q(P, \boldsymbol{X_D}) \tag{2}$$

$$Q_S = Q_D \tag{3}$$

Where P is the market price, Q_i $(i=D, S)$ is the quantity demanded or supplied, and $\boldsymbol{X_i}$ $(i=D, S)$ is a vector of exogenous explanatory variables of demand and supply. Elasticities of demand and supply could be determined through the simultaneous estimation of Eqs. (1) and (2). However, the elasticities could not be estimated empirically due to insufficient open-market demand and supply data for Tanzania. The Tanzanian government market intervention restricted farmers' responses to prices until the late 1980s. Thus, supply and demand elasticities used in this research were obtained from previous studies of food crops in LICs. Selection of these elasticities will be discussed at the end of this section.

Assume β and η represent the supply and demand elasticities for Tanzanian maize production. These parameter estimates correspond to supply and demand elasticities for the marketable share of maize in Tanzania. Supply and demand elasticities are used in the derivation of changes in consumer and producer welfare from advances in extension and research. k is the rate of shift in the production function due to technological change. The variable k is given by

$$k = \left(\frac{1 - Y_u}{Y_i}\right)\gamma \tag{4}$$

where Y_u represents average yield of the unimproved variety, Y_i represents average yield of the improved variety, and γ represents the rate of adoption. The rate of adoption is defined as the ratio of acreage planted to improved varieties to total planted acres of maize.

Following Hayami and Herdt (1977), constant elasticities of supply and demand, values of the rate of shift in the production function, and rate of adoption can be used to approximate the area of trapezoids corresponding to various consumer and producer attributes. Hence, the change (Δ) in price (P), quantity (Q), consumer surplus (CS), producers' cash revenue (PCR), producer surplus (PS), and production cost (PC) can be approximated using the following formulas:

$$\Delta P \approx \frac{k}{\beta + \eta} \tag{5}$$

$$\Delta Q \approx \frac{k\eta}{\beta + \eta} \tag{6}$$

$$\Delta \mathrm{CS} \approx \frac{kr}{\beta + \eta} \tag{7}$$

$$\Delta \mathrm{PCR} \approx \frac{k(\eta - r)}{\beta + \eta} \tag{8}$$

$$\Delta \mathrm{PS} \approx k\left[\frac{\eta - r + \beta(1 - r)}{(\beta + \eta)(1 + \beta)}\right] \tag{9}$$

$$\Delta \mathrm{PC} \approx \frac{k\beta(\eta - 1)}{(\beta + \eta)(1 + \beta)} \tag{10}$$

where the variable r refers to the amount of off-farm marketable surplus, i.e., $(1 - h)$. Comparative statistics of Eqs. (5)–(10) provide insight into the effects of the marketable surplus and the rate of technology shift on relevant consumer and producer attributes. Changes in PS and CS are the main focus in this analysis. Thus, note that changes in both PS and CS are increasing functions of an increase in the rate of technology shift. Similarly, the change in CS increases with an increase in the amount of marketable surplus. Alternatively, the amount of marketable surplus is inversely related to PS. Comparative statistics and sensitivity tests yield that changes in PS and CS are relatively insensitive to computed values of the supply and demand elasticities in a given range (Akino and Hayami, 1975). Thus, differences in CS and PS are primarily due to changes in the rate of adoption of new technologies and the share of marketable surplus.

Finally, values of change in CS and PS can be used to quantify the overall effects on CS and PS. These values are expressed as

$$\mathrm{CS} \approx P_0 \cdot Q_0 \cdot \frac{kr}{\beta + \eta} \tag{11}$$

$$\mathrm{PS} \approx P_0 \cdot Q_0 \cdot k\left[\frac{1 - r + \beta(1 - r)}{(\beta + \eta)(1 + \beta)}\right] \tag{12}$$

where P_0 and Q_0 refer to price and quantity prior to the inception of advances in maize production from extension and research. The above equations can be used to determine welfare gains from maize extension and research by sectors of the Tanzanian economy.

Demand elasticities chosen for this analysis were 0.65, 0.73, and 0.85, which are in the range of demand elasticities of staple crops in LICs estimated by Stevens and Jabara (1988) and Houthakker (1991). Additionally, Hayami and Herdt (1977) and Behrman and Murty (1985) estimated supply elasticities in the range of 0.30–0.50 for staple food crops in LICs. These values are used for this study as Tanzanian producers typically do not have the capital requirements to diversify to new crops, yet some price responsiveness exists from the producers' ability to either plant more or less in response to the expected market price.

3. Data

Annual production data were obtained from various sources for the period 1973–1992 (United Republic of Tanzania, 1999; United States Department of Agriculture, 1999; Food and Agriculture Organization of the United Nations, 1999). Data used to derive levels of technical adoption and on-farm consumption were available from a farm survey conducted during 1995 through a joint effort between the Southern Africa Coordination Center for Agriculture Research (SACCAR), the Tanzanian Department of Agricultural Research and Development, and the International Maize and Wheat Improvement Center (CIMMYT).

A two-stage stratified random sampling technique was used to select 640 farmers from the seven agroecological zones of Tanzania.[1] This survey was directed at small farms having less than 40 ha. Sample size was based on the relative importance of maize production. On average, 18 farmers were sampled from each village in each agroecological zone. It was possible from this collected data to calculate values of the rate of adoption (γ), the rate of technology shift (k), and the amount of marketable off-farm surplus (r).

The rate of adoption of improved maize varieties increased from an average of 20% in 1976 to 60% in 1994. The rate of adoption differed across agroecological zones. The lowest rate of adoption in 1976 was 10% (semiarid central zone) and the highest rate was 35% (Southern Highlands). As the rate of adoption increased over years, the average maize yield of improved seeds increased as depicted in Fig. 2. Yield of unimproved varieties did not increase significantly over the period under review. In 1974, the average yield of unimproved varieties averaged 0.2 ton/ha as compared to only 0.1 ton/ha for the improved varieties. However, as farmers learned how to manage improved maize seed, a technology cross-over occurred In 1985. In 1994, average yield of the improved varieties was 0.5 ton/ha compared to 0.27 ton/ha for unimproved varieties.

[1] This survey distribution by data zone for villages and farms sampled was West six and 114, North seven and 125, East 10 and 90, Central three and 54, South two and 36, Southern Highlands three and 59, and Lake Zone nine and 162.

Table 1
Estimates of percentage change in Tanzanian CS and producers' income due to technical progress in maize production for $k=7$

	$\eta_1=0.60$		$\eta_1=0.73$		$\eta_1=0.85$	
	$\beta_1=0.30$	$\beta_1=0.50$	$\beta_1=0.30$	$\beta_1=0.50$	$\beta_1=0.30$	$\beta_1=0.50$
$r=0.40$						
Price	−7.78	−6.36	−6.80	−5.69	−6.09	−5.19
Quantity	4.67	3.82	4.96	4.15	5.18	4.41
CS	3.11	2.55	2.72	2.28	2.43	2.07
Producers' cash revenue	−1.20	−0.85	−1.73	−1.25	−2.11	−1.56
Production cost	−0.72	−0.85	−0.42	−0.51	−0.21	−0.26
PS	2.72	2.12	2.67	2.39	2.95	2.59
$r=0.60$						
Price	−7.78	−6.36	−6.80	−5.69	−6.09	−5.19
Quantity	4.67	3.82	4.96	4.15	5.18	4.41
CS	4.67	2.55	4.08	3.41	3.65	3.11
Producers' cash revenue	0.00	0.00	0.68	0.49	1.17	0.86
Production cost	−0.72	−0.85	−0.42	−0.51	−0.21	−0.26
PS	0.72	0.85	1.31	1.25	1.73	1.56

4. Determination of welfare gains

Table 1 summarizes the percentage change in price, quantity, CS, producers' cash revenue, production costs, and PS from a shift in the rate of supply of maize from advances in extension and research. These values were determined to be 7% for the rate of technological shift due to advancements in extension and research and 40% for the percent of off-farm marketable surplus. Both values represent average values for the period of crop years from 1976–1977 to 1994–1995. Note that the rate of technological shift is a static value, and for changes in social benefits to continue as described in Table 1, the value of k must continue to shift the supply curve out by a similar amount in the future. A second value of the rate of marketable surplus was used ($r=60\%$) to aid in distinguishing two factors: how will social benefits be distributed if there continues to be an increase in the rate of adoption and how do large producers rate relative to small producers? [2]

Price and quantity values do not change with the level of off-farm marketable surplus. As expected, price was found to decline and quantity was found to increase from a positive shift in the supply curve due to a technology shift. Only a slight decrease in production costs was found. More than offsetting this decrease was the increase in the producers' cash revenue. CS and PS were found to have a similar percentage increase with 40% marketable surplus. As hypothesized, the percent change in the distribution of social benefits is relatively insensitive to chosen values of the elasticities of supply and demand.

Of interest in Table 1 are the comparisons made between changes in social benefits for the amount of off-farm marketable surplus (r) of 40 and 60%. Producers' cash revenue was found to decline substantially with an increase in off-farm surplus. Similarly, the gap between changes in CS and PS is substantially different as off-farm surplus (r) increased. The consumer clearly gains more than the producer for a larger value of r.

In Table 2, welfare gains are expressed in millions of Tanzanian Shillings with 1976–1978 used as the base period prior to substantial gains in maize production from extension and research. Chosen values of elasticities of supply and demand represent the mode of the elasticity of demand and the two values for the elasticity of supply. The top portion of Table 2 reports consumer and producer welfare gains for a relatively small farm ($r=40\%$). Computed welfare gains indicate that consumers and producers gain equally from extension and research efforts. The total welfare gains

[2] The value of 60% represents the upper 25th percentile of farms evaluated in the survey.

Table 2
Distribution of economic gains from technical progress assuming $k=7$ and $\eta=0.72$[a]

Welfare gains (million Shillings)[b]	$\beta_1=0.30$	$\beta_1=0.50$
$r=0.40$		
Consumer	432.00 (51%)	362.00 (49%)
Producer	424.00 (49%)	380.00 (51%)
Total	856.00 (100%)	742.00 (100%)
$r=0.60$		
Consumer	648.00 (76%)	542.00 (73%)
Producer	208.00 (24%)	199.00 (27%)
Total	856.00 (100%)	741.00 (100%)

[a] Percentage of total welfare gains in parentheses.
[b] 1976–1978 average price and quantity.

change considerably with an increase in the elasticity of supply, but the percentage benefit changes only marginally. A small producer would be expected to have a lower elasticity than a relatively large producer as the small producer would have difficulty switching cropping practices. Thus, different supply elasticities correspond to different sizes of the producer in the small ($r=40\%$) and large ($r=60\%$) producer category.

A larger differentiation in welfare gains can be observed for the case of 60% off-farm marketable surplus. For this case, the consumer was determined to receive from 73 to 76% of the welfare gains, while the producer gained approximately 25% of the total gains. Relatively large producers clearly realize small welfare gains per unit of grain produced from extension and research efforts and may not have a strong incentive to support such activities if taxed proportional to production. Distribution of welfare was insensitive to changes in demand elasticity. An increase in the elasticity of demand decreased both CS and PS minimally.

5. Policy implications and conclusions

Maize is the staple food crop for Tanzania as it provides 70% of the energy and 50% of the protein requirements for the Tanzanian population. Worsening economic conditions have reduced government funding in extension and research. Hence, for maize extension and research programs to continue, consumers and producers must begin to bear an increasing share of the costs associated with funding of the programs. This study determined the welfare distribution of maize extension and research benefits. This information was used to make inferences as to the distribution of a taxing schedule between consumers and producers.

Implementation of the collection of food crop research taxes from urban consumers may prove difficult since in low income societies, such as Tanzania, the urban consumers generally have political clout in contrast to high income countries (Missiaen and Lindert, 1993). Taxation of food leads to higher prices which hurt low income urban dwellers. In some cases, such high food prices spark off riots as was the case in Zambia in 1986 (Mwanaumo et al., 1997). Though no such riots have occurred in Tanzania since food marketing liberalization in 1986, policy makers are always reluctant to tax food for urban consumers. However, for food crop research to continue, taxation of food appears inevitable. If both producers and consumers are taxed fairly, the tax base will be broadened, and hence, the tax burden will be less stringent to politically sensitive urban consumers.

The current taxation of food grain is implemented by local governments in both cities and villages. The tax collection centers are at road blocks located strategically on roads leading in and out of major trading centers. Maize is assessed a nominal tax based on the number of bags carried in the trucks. However, the tax revenue is used for development activities not necessarily related to maize research and development. Thus, implementation of a maize research tax would be easier since a taxation system is already in place.

Results from the present study indicated that, with a calculated off-farm market surplus of 40% and a 7% rightward shift in maize production due to advances in extension and research, consumers and producers gain equally. This suggests that consumers and producers should share equally in a revenue generating tax for funding maize research and extension programs. However, for large producers (off-farm surplus of 60%), their percent welfare gain is far less than consumers. If a taxing schedule is developed, then taxation of large producers should decrease proportionally with the amount sold. Alternatively, if large-scale producers are to have the incentive to increase production, compensation through direct government payments may be needed.

Care must be taken in deriving a taxing schedule for urban consumers in LICs since they (urban consumers) have political clout that may lead to instability. A prohibitive tax on consumers would be met with resistance. On the other hand, a high tax on producers, especially large scale farmers, may create a disincentive for the production of marketable surplus. This will, in turn, increase food shortages in urban areas and may cause political unrest. Policy makers can avoid this by ensuring that the food crop research tax burden is shared in an equitable manner.

6. List of symbols

O	is the origin when primary consumption occurs off-farm as in high income countries
H	is the origin when primary consumption occurs on-farm as in LICs
D	represents the demand curve for marketable surplus
D_{H}	represents the demand curve for on-farm consumption
S_0	represents the supply curve prior to advances in technology due to extension and research
S_1	represents the supply curve after advances in technology due to extension and research
P_0	represents the equilibrium price prior to advances in technology due to extension and research
P_1	represents the equilibrium price after advances in technology due to extension and research

Acknowledgements

Helpful comments by David Norman, Chien-Pang Lin, Arlo Biere and two anonymous reviewers on earlier drafts of this manuscript are gratefully acknowledged. The authors also wish to thank the government of Tanzania, the Southern Africa Coordination Center for Agriculture Research (SACCAR) and the International Maize and Wheat Improvement Center (CIMMYT) for funding this study.

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