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Economic impacts of cassava research and extension in Malawi and Zambia

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This paper estimates the economic impacts of cassava research and extension in Malawi and Zambia over the period 1990-2008. The data come from sample household surveys, planting material production records, and a series of cassava improvement experiments conducted in the two countries. Past investments in cassava improvement have led to the development and release of a good number of high-yielding and cassava mosaic virus disease (CMD)-tolerant cassava varieties. The results show relatively higher adoption rates for the CMD-free local varieties compared to CMD-tolerant varieties that have been released in the two countries. The adoption of new varieties has been low and slow largely due to the fact that most of these varieties lacked the consumption attributes highly valued by farmers. The multiplication and distribution of CMD-free planting materials of the recommended local varieties led to greater adoption, but infection with CMD three to four years after adoption meant that the yield gains and economic benefits could not be sustained. Nevertheless, the multiplication and distribution of clean cassava planting materials generated a modest rate of return of 24%, which is actually consistent with an earlier rate of return estimate of 9 to 22% for cassava improvement in developing countries. Analysis of the ex ante impacts of current and future investments in cassava improvement shows that cassava improvement research that focuses on the development and dissemination of varieties with highly preferred consumption and industrial attributes would yield a greater rate of return of 40%.

Key words: Adoption, cassava, economic surplus, impact, Malawi, Zambia.

INTRODUCTION

Cassava is Africa's second most important food staple after maize and provides more than half of the dietary calories for over 200 million people (Nweke et al., 2002). In Malawi, cassava is a staple food for more than 30% of the population and occupies 60% of the area under roots and tubers and nearly 50% of the total production. Cassava has wide agro-ecological adaptation, but the main growing areas are the northern belt along the lakeshore (Karonga, Rumphi, Nkhatabay, and Nkhotakota), the southern cassava belt (Mangochi, Machinga, Zomba, and the southern Shire Highlands), and the central belt of Dedza and Lilongwe. The marketed surplus of cassava increased from 11% in 2002 to 75% in the central region and 60% in the southern region (Mataya et al., 2001; Phiri, 2001; Haggblade and Zulu, 2003). The fresh market takes up about 80% whereas the remainder is absorbed in the manufacturing and confectionary industries. Similarly, in Zambia, cassava accounts for roughly 15% of national calorie consumption (Dorosh et al., 2007) and is mostly grown in the five provinces of Luapula, Northern, North-Western, Copperbelt, and Western provinces where the crop is regarded as a staple

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(Soenarjo, 1992). The importance of the crop is fast increasing such that in the recent years cassava production has expanded to the Southern and Eastern parts of the country (Chitundu, 1999).

The expansion of cassava production in Africa in the face of longstanding as well as emerging threats to cassava production and productivity is largely attributed to sustained investments in research and extension aimed at addressing a wide range of biotic and abiotic constraints (Nweke et al., 2002). One of the major biotic constraints to cassava production is cassava mosaic virus disease (CMD) and is transmitted by the whiteflies and infected cuttings. Since recently, cassava brown streak virus disease (CBSD) has become yet another major constraint to cassava production. As part of a major long term crop improvement effort since its creation in 1967, the International Institute of Tropical Agriculture (IITA) initiated cassava research in the early 1970s with a focus on developing varieties with resistance to major diseases such as CMD. Cassava breeding was initiated using breeding materials from Moor plantation near Ibadan and a limited number of east African landraces with resistance to CMD developed through interspecific hybridization in the 1930s (Haggblade and Zulu, 2003). This work resulted in several elite genotypes that had resistance

to CMD as well as high and stable yields and good consumer acceptability. The development of these resistant varieties, and their delivery to national programs for testing under specific local conditions during the late 1970s and 1980s, has led to the successful deployment of CMD-resistant cassava in Sub-Saharan Africa (Nweke et al., 2002). In addition to their resistance to CMD, the improved varieties combine enhanced postharvest qualities, multiple pest and disease resistance, wide agro-ecological adaptation, and greatly improved yield potential where yield increases of 50-100% without the use of fertilizer were demonstrated in many African countries.

The national cassava improvement programs in Malawi and Zambia have developed and released varieties that outperform the local varieties using breeding materials received from IITA. The improved genetic materials from IITA, referred to as the Tropical Manihot Selections (TMS), were distributed to several countries in the cassava-growing belt of eastern and southern Africa during the late 1980s at a time when governments were dismantling large-scale maize subsidy programs. Over the period 1990–2011, IITA and the respective national programs released a total of 12 improved varieties in Malawi and 8 improved varieties in Zambia. The improved cassava varieties coupled with the declining profitability of maize due to the withdrawal of subsidies contributed to a surge in cassava production in Malawi and Zambia beginning in the early to mid-1990s (Haggblade and Zulu, 2003). The increased availability of improved cassava varieties opened up a range of profitable commercial opportunities for production of cassava-based foods, feeds, and industrial products. At the same time, improved disease tolerance and higher productivity as well as a flexible harvesting calendar offered prospects for improving household food security.

Despite major efforts to develop and disseminate a growing number of improved varieties, there is lack of comprehensive evidence on the adoption and economic impacts of improved cassava varieties. This paper used household survey data as well as planting material production estimates for measuring variety adoption and on-farm experimental data for estimating yield gains.

Cassava research in Malawi and Zambia

Cassava improvement dates back to the 1930s in Malawi and 1940s in Zambia. Cassava was then regarded as an important famine reserve crop and each household was encouraged to have a piece of land under cassava as a fallback plan. The research focus then was on agronomic practices as well plant health in order to generate information on local planting conditions and select mosaic disease tolerant varieties. In Malawi, some 22 local varieties were characterized and put under mosaic observations at Mulanje and other stations together with a number of new introductions from Amani in north-east Tanzania. Cassava production expanded following the removal of fertilizer subsidies in the late 1980s and the droughts in the early 1990s which required an emergency response involving accelerated multiplication and distribution of planting materials of the best local varieties.

In Malawi, the Root and Tuber Crops Research Program was established in 1978, whereas the Zambia Root and Tuber Improvement Program (RTIP) was established in 1979. National cassava research activities initially focused on identification of best local varieties, cleaning, and distribution of planting materials. The national programs in both countries adopted IITA's breeding scheme in order to speed up selection, evaluation, and release of new varieties. The varieties released by the root and tuber improvement programs have IITA parent material introduced directly in the form of tissue culture or seed population (Tables 1 and 2). The cassava breeding program in Malawi released three waves of improved cassava varieties: first the best local varieties (Chitembwere, Gomani, Mbundumali, and Nyasungwi) were released in the 1980s and recommended to farmers on the basis of mosaic virus tolerance and early bulking. In 1992, IITA through SARRNET launched a three-year drought recovery program of accelerated multiplication and distribution of cassava planting materials. This program targeted to provide planting materials to 300,000 smallholder farmers throughout the country. Under the same program in 1995 there was massive planting material multiplication and

Table 1. Improved cassava varieties released in Malawi, 1980–2002.

Variety	Category	Release year	IITA material used	Major attributes			
				Yield (t/ha)	Maturity (MAP)	Taste	Disease tolerance
Nyasungwi	Local selection	1980s	None	12-21	12-15	Semisweet	
Chitembwere	Local selection	1980s	None	20-23	15-18	Sweet	
Manyokola	Local selection	1980s	None	25	9-15	Sweet	Tolerates CGM, CBSD but is susceptible to CMD
Gomani	Local selection	1980s	None	25	9-12	Bitter	Susceptible to CGM, CBSD, CMD
Mkondezi (MK91/478)	Improved	1999	Seed population	40	9-15	Bitter	Tolerates CMD and CM
Maunjili (TMS 91934)	Improved	1999	IITA introduction	35	9-12	Bitter	Tolerates CMD, CM and CGM
Silira (TMS 60142)	Improved	1999	IITA introduction	25	12-15	Bitter	Tolerates CMD and CM but is susceptible to CGM
Sauti (CH92/077)	Improved	2002	IITA seed population	25	12-15	Bitter	Tolerates CMD, CM and CGM
Yizaso (CH92/112)	Improved	2002	IITA seed population	25	12-15	Bitter	Tolerates CMD, CM and CGM
Phoso (LCN 8010)	Improved	2008	IITA introduction	35	9-15	Bitter	Tolerates CMD and CBSD
Mulola (TMS 83350)	Improved	2008	IITA introduction	40	9-15	Bitter	Tolerates CMD, CM, and CGM
Sagonja (CH92/082)	Improved	2009	IITA seed population	25-35	9-15	Bitter	Tolerates CMD, CBSD, CM, and CGM
Chiombola (TME 6)	Improved	2009	IITA introduction	45	9-15	Bitter	Tolerates CMD and CGM

distribution of existing cassava clones, including Gomani and Mbundumali (Haggblade and Zulu, 2003). The second phase of the accelerated multiplication and distribution program targeted the establishment of 15,000 hectares of cassava nurseries to be eventually distributed to 75,000 farmers. The second series of varieties came out of hybridization and screening trials which started in 1992 from which process three new clones were identified and released in May 1999 (Mkondezi, a bitter variety; Silira, categorized as semi-sweet, and Maunjili, a bitter variety). In 2002 a further two bitter varieties (Sauti and Yizaso) were released. These new varieties increased yield by about 54% from the already high 13 tons per hectare for the best CMD-free local varieties (Gomani and Mbundumali) to 20 tons per hectare (Benesi et al., 1999).

In Zambia, the breeding program by the Root and Tuber Improvement Program has led to two waves of varietal releases, the first was in 1993 and the second in 2000. In 1993, three varieties, namely Bangweulu (LUC55), Kapumba (LUC327), and Nalumino (LUC304), were released. These varieties have higher yield ability and possess superior attributes compared to other traditional cassava varieties (Table 3). Historically the heavy fertilizer subsidies provided a strong incentive for maize production in the country. However, these recommended varieties coincided with a policy shift towards cassava production following the removal of fertilizer subsidies (Haggblade and Zulu, 2003). Starting from 1988/89 there were a series of multiplication and distribution of cassava planting materials to respond to the increased demand for cassava material in the country. Through efforts of the Zambian Root and Tuber Improvement Program and a consortium under Program Against Malnutrition (PAM) engaged in the distribution of cassava planting materials, a total of 552,000 cuttings were distributed in three consecutive seasons (1989-1992) to individual farmers looking for planting materials Soenarjo, 1992). Most of the cassava materials were susceptible to cassava mosaic, but a local clone called Nalumino was identified as being resistant and has been used in breeding program as a source of resistance (Soenarjo, 1992).

Table 2. Improved cassava varieties released in Zambia, 1990–2000.

Variety	Category	IITA material	Year of release	Yield (t/ha)	Maturity (MAP)	Taste
Bangweulu	Local selection	None	1993	31	12-16	Bitter
Kapumba	Local selection	None	1993	22	16-24	Sweet
Nalumino	Local selection	None	1993	29	16-24	Bitter
Mweru	Improved	IITA male x Nalumino	2000	41	16	Sweet
Chila	Improved	IITA male x Nalumino	2000	35	16	Bitter
Tanganyika	Improved	IITA male x Nalumino	2000	36	16	Sweet
Kampolombo	Improved	IITA male x Nalumino	2000	39	16	Sweet

Source: Haggblade and Nyembe (2008).

Table 3. Average yields of cassava varieties across districts in Malawi.

District	Yield (tons/ha)		
	Local CMD-infected	**Local CMD-free**	**Improved CMD-resistant**
Nkhatabay	12	17	17
Mzimba	12	12	9
Nkhotakota	11	16	17
Lilongwe	10	11	11
Zomba	7	11	12
Mulanje	6	9	20
All	9	12	14
Yield gain (%)	**-**	**33**	**55**

The conventional breeding program was also started in 1988/89 in Mansa with 15,077 (seedlings from twelve different crosses (Soenarjo, 1992). By 1992, preliminary evaluation identified 15 clones as being tolerant to CMD. Further evaluations led to the release of four new varieties of Mweru, Chila, Tanganyika, and Kampolombo in 2000 (Soenarjo, 1992). A total of four out of the seven or 57% of the released varieties had IITA parent material crossed with best local variety in order to enhance local adaptation and variety attributes.

MATERIALS AND METHODS

The economic surplus method for ex-post impact analysis

Several impact studies of agricultural technologies have estimated aggregate economic benefits through extrapolation of farm-level yield or income gains using partial equilibrium simulation models such as the economic surplus model (Alston et al., 1995). The economic surplus method is the most widely used procedure for economic evaluation of benefits and costs of a technological change. Technological change due to research in agriculture increases the yield or reduces the cost of production once the new technology is adopted. If the new technology is yield increasing, the producer sells more of the good in the market and if demand is downward-sloping the price decreases. Technology adoption reduces the per-unit cost of production and hence shifts the supply function of the commodity down and to the right. If the market for the commodity is perfectly competitive, this will lead to an increase in the quantity exchanged in the market and a fall in price. As a result, consumers benefit from the price reduction and producers may benefit from selling a greater quantity.

The basic model of research benefits in a closed economy is shown in Figure 1. The demand for the commodity is denoted by D, whereas the pre-research supply curve is S_0 and the post-research supply curve following technological change is S_1. The initial equilibrium is denoted as (P_0, Q_0), while the post-research equilibrium is (P_1, Q_1). That is, the initial equilibrium price and quantity are P_0 and Q_0, whereas after the supply shift they are P_1 and Q_1. The total benefit from the research-induced supply shift is equal to the area beneath the demand curve and between the two supply curves (ΔTS=area *abce*). The total benefit comprises the sum of benefits to consumers (ΔCS=area P_0bcP_1) and the benefits to producers in the form of the change in producer surplus (ΔPS=area P_1ce minus area P_0ba). Under the assumption of a parallel shift (so that the vertical difference between the two curves is constant) area I_0de equals area P_0ba.

This allows estimation of the economic surplus in a closed economy as follows: (1) Economic Surplus $\Delta TS=P_0Q_0K_t(1–0.5Z_t\eta)$ for ex-post analysis and $\Delta TS=P_0Q_0K_t(1+0.5Z_t\eta)$ for ex-ante analysis of potential impacts; (2) consumer surplus $\Delta CS=P_0Q_0Z_t(1–0.5Z_t\eta)$ for ex-post analysis and $\Delta CS=P_0Q_0Z_t(1+0.5Z_t\eta)$ for ex-ante assessment of potential benefits to consumers; and producer surplus $\Delta PS=(K_t-Z_t)P_0Q_0(1–0.5Z\eta)$ for ex-post analysis and $\Delta PS=(K_t-Z_t)P_0Q_0(1+0.5Z\eta)$ for ex-ante assessment of potential benefits to producers. In this model, K_t is the supply shift representing per-unit cost reduction due to technological change and derives from net yield gains due to research and technology adoption rates, whereas $Z = K_t\varepsilon/(\varepsilon+\eta)$ represents the percentage

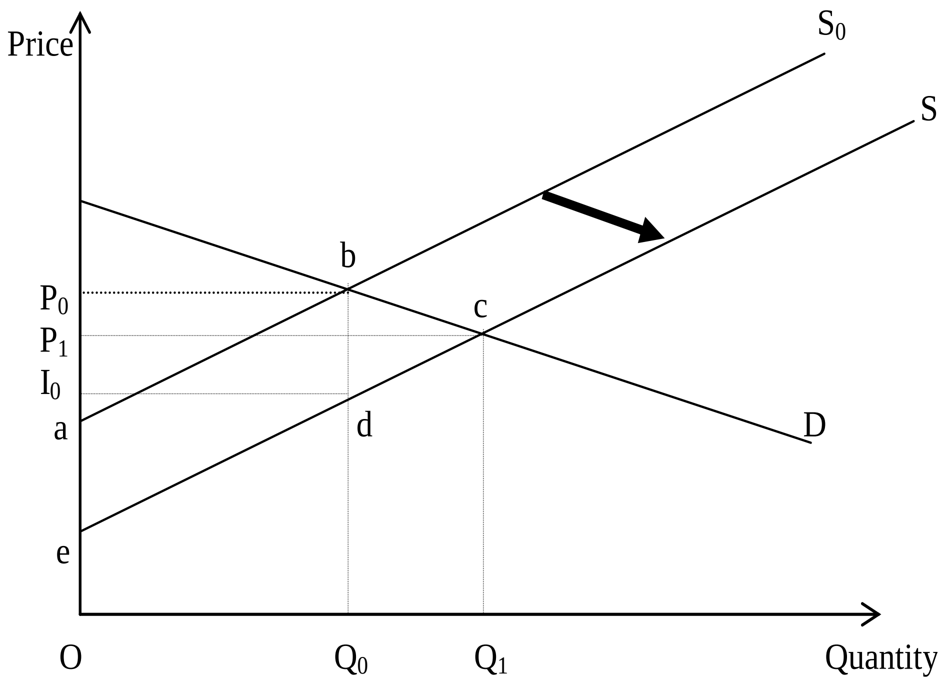

Figure 1. Effects of technological change on producer and consumer surplus.

reduction in price due to the supply shift and ε and η are price elasticity of supply and demand, respectively. Similarly, Alston et al. (1995) show that in a small open economy, change in economic surplus is equal to change in producer surplus and can be calculated as $\Delta TS=\Delta PS=P_wQ_0K_t(1+0.5K_t\varepsilon)$ for ex-post analysis and $\Delta TS=\Delta PS=P_wQ_0K_t(1+0.5K_t\varepsilon)$ for ex-ante analysis of potential impacts of research, where P_w is the real world price.

The research-induced supply shift parameter K_t is the single most important parameter influencing total economic surplus resulting from unit cost reductions. Following Alston et al. (1995), the supply shift was derived as:

$K_t=[(\Delta Y/Y)/\varepsilon-(\Delta PC/PC)/(1+\Delta Y/Y)]A_t,$

Where, ΔY/Y is the proportional yield increase per hectare, given that research is successful and the resulting innovation fully adopted; $\Delta PC/PC$ is the proportional increase or decrease in the variable production costs required to achieve the yield increase; and A_t is the rate of adoption of the innovation at time *t*. For improved performance, the adoption of improved verities may require some investment in new inputs like improved seeds or planting materials, chemical fertilizer, pesticide and more labor in operations. Such investments constitute adoption costs required to achieve the necessary yield advantage that improved varieties have over the traditional varieties. However, cassava is famous for its ease of cultivation and does not require more extensive use of labor than is required for the traditional varieties. In view of this, the supply shift equation reduces to $K_t=[(\Delta Y/Y)/\varepsilon]A_t$.

Data sources

Adoption of improved varieties

Adoption rates of improved cassava varieties over the years were estimated based on data coming from household surveys and planting material distribution efforts. In Malawi, a survey of adoption of improved cassava varieties was conducted in 2007. In Zambia, on the other hand, variety adoption data for 2007 were obtained from the Central Statistical Office. The adoption profiles of improved cassava varieties over time were derived using the S-shaped logistic function (Griliches, 1957), which has been used widely to analyze adoption patterns over time (Maredia et al., 2000; Feder et al. 1985; CIMMYT, 1993; Bantilan et al. 2005). Specifically, the diffusion of improved cassava varieties was assumed to follow a logistic curve given as a sigmoid function of time *t,* $Y_t = K[1-e^{-(a+bt)}]^{-1}$, where *K* is the long-run upper limit on adoption; *b* is the slope coefficient measuring the rate of acceptance of the new technology; and *a* is the intercept reflecting aggregate adoption at the start of the estimation period (Feder et al. 1985; CIMMYT, 1993).

The results of the adoption survey in Malawi showed generally high adoption of the local selection *Manyokola,* which is highly preferred by farmers but is susceptible to CMD. Only 7% of the farmers adopted improved varieties (that is, *Mkondezi*, *Silira*, *Maunjili*, *Sauti,* or *Yizaso*) that are tolerant to CMD but are less preferred by farmers due to lack of good consumption attributes. Improved cassava varieties like *Mkondezi* were mostly reported in the north by 7% of the sampled farmers, whereas *Silira* was found to be popular (10%) in the central region. Similarly, in Zambia, local varieties are still popular among cassava growers and thus the largest share of cassava area (over 70%) is still under local varieties. Eight years after their release, the improved varieties (Chila, Mweru, Tanganyika, and Kampolombo) have not been widely adopted. The results showed adoption rates of about 15% in 2007 for improved cassava varieties in Zambia. Nearly 75% of the households surveyed in Malawi cited lack of planting materials and information regarding their availability as the major constraint to the adoption of improved cassava varieties. Awareness, access to planting materials, and farmer perception are important factors in the adoption of improved varieties. Variety adoption will not take place unless farmers are aware of the varieties that exist and have access to planting materials.

Table 4. Average yields of cassava varieties across stations in Malawi, 1990–1997.

Varieties	Station					
	Mkondezi	Chitala	Chitedze	Bvumbwe	Makoka	National
Improved	Yields (tons/ha)					
Mkondezi	25	17	16	18	19	20
Maunjili	20	21	21	17	25	21
Yizaso	17	-	-	5	13	13
Silira	15	17	11	11	16	14
Sauti	-	17	-	-	-	17
Mean (Y_1)	19	19	16	15	20	18
Local						
Manyokola	7	16	16	11	21	13
Gomani	15	17	9	6	13	13
Chitembwere	12	12	13	3	12	11
Nyasungwi	10	11	-	4	17	11
Mean (Y_0)	12	15	12	9	17	13
$(Y_1-Y_0)/Y_0$ (%)	58	31	27	80	20	42

Source: Calculated from various SARRNET reports.

Table 5. Average yields of cassava varieties in Zambia, 2002-2004.

Variety	Lusaka province		Mansa	Mean	Yield gain (%)
	Yield 15 MAP	Yield 16 MAP	Yield 16 MAP		
Bangweulu (local, CMD-free)	21.30	22	31	24.8	21
Chila	18.20			18.2	
Mweru (Improved, CMD-resistant)	19.60	26	41	28.9	41
Muganga (local check)	20.50			20.5	
Manyokola	11.00			11.0	

Source: Calculated from various SARRNET reports.

Recognizing the high preference of farmers for the local selection *Manyokola* but also the high susceptibility of this variety to CMD, IITA and national program partners focused early efforts on the multiplication and distribution of CMD-free planting materials using tissue culture-based cleaning technology. The ex-post impact analysis in this study focuses first on this aspect of the IITA-led cassava improvement effort in Malawi and Zambia. The logistic function was used to estimate the adoption pattern of the CMD-free planting materials from 1993 to 2010 (Fig. 2). IITA and the national programs participated in the multiplication and distribution of clean cassava planting materials. As a result of such multiplication and distribution efforts, the area under improved and CMD-free local varieties reached an estimated 13% of the cassava area in 2003.

Yield gains due to research

Table 3 presents average yields of local and improved cassava varieties based on the household survey of adoption. The results show significant yield differences between the improved and traditional cultivars in the country. The average yield for CMD-free and newly released improved varieties were 12 tons/ha and 14 tons/ha, respectively, compared to 9 tons/ha for CMD-infected local varieties. This translates to a corresponding 33 and 55% yield gains through disease-free local varieties and newly bred varieties, over the generic local varieties. Manyong et al. (2000) reported that the improved cassava varieties have a yield advantage of up to 63% over local varieties grown under similar farmer-managed field conditions. The effects of cassava improvement program (either through cleaning or breeding) were dominant in all ecological zones as evidenced by significant yield gains for the CMD-free cassava varieties as well as improved cassava varieties over local check.

For purposes of comparison, the experimental yields recorded at five research stations in Malawi from 1990 to 1997 are presented in Table 4. The experimental results show that the yield gains for new varieties over local varieties range from 30 to 58% depending on the region but the national average was estimated at 42%.

In Zambia, experiments were conducted at Mansa research station and in Lusaka province from 2002 to 2004. These results are presented in Table 5. The experimental results show that variety Bangweulu gave 25 tons/ha compared to 21 tons/ha for Muganga, whereas Mweru, one of the improved varieties bred by the Zambian root and tuber improvement program, produced 29 tons/ha. Despite data limitations, this still demonstrates the marked effects of using CMD-free local varieties as well as improved varieties, with respective yield gains of 21 and 41% over the localcheck Muganga.

Supply and demand elasticity estimates for cassava

Supply elasticity estimates for cassava in Malawi and Zambia were not readily available. However, Masters et al. (1996) generalize estimates for supply elasticity to be within the range of 0.2-1.2 but are usually low for major crops with little expansion potential because they already take up large share of available resources. Alston et al. (1995) proposed unitary supply elasticity in the absence of exact measures indicating that a one percent increase in cassava prices would lead to an increase in cassava supply by the same margin. The relevant estimates for demand elasticity range from 0.4-10 and are lower for food crops in a small market and higher for export crops or import substitutes whose sales can grow quickly (Masters et al., 1996). Other studies in the recent past like Deaton (1989), Tsegai and Kormawa (2002), Alene et al. (2009) and Dorosh et al. (2009) reported price elasticity of demand of 0.33, 0.46, 0.38, and 0.20, respectively. Dorosh et al. (2009) found that a 10% price increase would reduce the demand for cassava products by 2%. On the basis of past empirical work and given the unique features of cassava as a major staple, this study adopted unitary supply elasticity and demand elasticity of 0.2.

Cassava multiplication and distribution costs

Massive cassava multiplication and distribution program started in the 1992/93 season as a joint response to the 1991/92 drought season. Initially, the Government of Malawi and NGOs established cassava and sweet potato multiplication scheme on a small scale. In the 1992/93 season, the Government of Malawi through IITA/SARRNET (1993/94) and NGOs launched the first phase of the accelerated multiplication and distribution of cassava and sweet potato planting materials. This project was worth US$700,000 in which US$250,000 came from USAID/Malawi and US$450,000 was from United States Department of Agriculture/Overseas Famine Disaster Administration (USDA/OFDA). The funded activities were planned for two years from September 1992 to September 1994 but were granted two-year no-cost extension to September 1995 and later to March 1996. The project was quite successful in terms of increasing area under cassava production and raising cassava productivity hence a second phase of the program was initiated in 1998 in order to intensify and sustain the project achievements realized. The second phase of the accelerated multiplication and distribution program was planned for two years from December 1998 to May 2001. The implementation of activities in the second phase was also made possible through US$382,334 financial support from USAID-Malawi.

The accelerated multiplication and distribution projects were running concurrently with other cassava improvement activities like breeding which also had a component of seed multiplication and distribution. The first phase of SARRNET was a US$7 million regional project launched in 1994 where Malawi, Mozambique, and Zambia benefited US$130,000, US$145,000, and US$100,000, respectively, for five years up to 1998. In 1996 the United States Foreign Disaster Assistance/Bureau for Humanitarian Response (OFDA/BHR) committed US$4.6 million in the SADC multiplication and distribution activities. From this, Malawi and Zambia were allocated US$492,000 and US$651,000. In the 1997/98 season, IITA/SARRNET received another funding from USAID/OFDA under the project framework of Strategic Action Plan for Root and Tuber Crops for El Nino Southern Oscillation (SAP-RT) mitigation in Eastern and Southern Africa. Malawi benefited with US$21,500 and Zambia got US$26,000. Zambia also got extra resources from USAID-Zambia in 1998 to the tune of US$781,700 for purposes of distributing disease free planting materials to the farmers.

The SARRNET phase II operating with a budget of US$3.5 million started in 1999 and ended in September 2002. At the end of the project period, US$895,460 was still available and was committed for a one year no-extra cost extension to September 2003. Between September 2003 and August 2004, a US$257,000 USAID/RCSA crop diversification and enhanced productivity was implemented under the umbrella project of improving rural livelihoods in Southern Africa where Malawi got US$48,000 and Zambia was allocated US$53,500.

From the year 1990 to 2008, a total of US$12 million is estimated to have been used for purposes of root and tuber crops research, multiplication and distribution of disease free planting materials in the SARRNET member countries. These expenses were incurred in the process of promoting planting materials for cassava and sweet potatoes in all the SARRNET countries. Based on the level of activities for the two crops, the costs were equally distributed such that 50% of the total costs accrued to cassava multiplication and distribution. This gives an average expenditure of US$0.32 million every year and a total of US$6 million as the investment in cassava research, multiplication and distribution program over the period of the analysis.

Cassava prices in Malawi and Zambia

The benefits for cassava multiplication and distribution (and the ex-ante benefits) are based on average domestic market prices prevailing in the two countries. In Zambia, the average cassava price was estimated at US$110 per ton dry weight after netting out the effect of inflation and was based on Otterdijk (1999), Haggblade and Zulu (2003), and Haggblade and Nyembe (2008). Otterdijk (1999) reported that farmers in 1994/95 season received an average price within the range of US$0.05 to US$0.08 per kilogram of fresh cassava root—equivalent to US$167–US$267 per ton dry weight using a conversion factor of 0.3 from fresh to dry weight. In another study, Haggblade and Zulu (2003) estimated that in 1985 producers got US$375/ha for a production of 6 tons/ha and in 2002 they realized US$675/ha for cassava yield of 12 tons/ha. This implied that the average cassava producer price was at US$63/ton in 1985 and US$56/ton in 2002. In a marketing margin analysis, Haggblade and Nyembe (2008) reported farm gate price of ZK10,000–ZK15,000 per 50 kg bag of dried cassava chips for the 2006 season. With the exchange rate in 2006 of US$1 to ZK3,500, this gives an average producer price of US$71/ton. For Malawi, cassava prices for the period 1990-2006 were readily available from FAOSTAT online publication. Therefore, the average price of about US$70 per ton of cassava was used in the ex-post analysis, whereas a four-year average price of US$138/ton dry weight (2003-2006) was used in the ex-ante analysis discussed below.

RESULTS AND DISCUSSION

Ex-post impacts of cassava research and extension

The estimated benefits from cassava research and extension involving multiplication and distribution of improved and CMD-free planting materials are presented in Table 6. In the base model, the stream of benefits and costs were compounded at a 5% rate to their respective 2008 values. The benefits were accumulated annually at a rate in tandem with that of cassava variety adoption and supply shift. The results show gross economic benefits of over US$17 million for Malawi and Zambia, which is equivalent to US$1 million per year for the two

Table 6. Benefits and costs of cassava improvement in Malawi and Zambia (US$ million).

Year	Malawi			Zambia			Total		NPV
	ΔTS	ΔCS	ΔPS	ΔTS	ΔCS	ΔPS	ΔTS	Costs	
1990	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.29	-0.12
1991	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.12	-0.05
1992	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.12	-0.05
1993	0.11	0.09	0.02	0.08	0.06	0.01	0.19	0.11	0.04
1994	0.05	0.04	0.01	0.10	0.09	0.02	0.15	0.96	-0.41
1995	0.04	0.04	0.01	0.14	0.12	0.02	0.18	0.73	-0.29
1996	0.72	0.60	0.12	0.18	0.15	0.03	0.90	0.69	0.12
1997	1.02	0.85	0.17	0.23	0.19	0.04	1.24	0.75	0.28
1998	1.11	0.93	0.19	0.33	0.28	0.06	1.45	0.50	0.58
1999	0.31	0.26	0.05	0.49	0.40	0.08	0.80	0.50	0.19
2000	0.81	0.67	0.13	0.49	0.41	0.08	1.29	0.49	0.55
2001	0.93	0.78	0.16	0.66	0.55	0.11	1.60	0.48	0.80
2002	0.53	0.44	0.09	0.75	0.62	0.13	1.28	0.47	0.60
2003	0.42	0.35	0.07	0.83	0.69	0.14	1.25	0.12	0.89
2004	0.51	0.42	0.08	0.90	0.75	0.15	1.40	0.12	1.06
2005	0.44	0.37	0.07	1.05	0.87	0.17	1.48	0.11	1.18
2006	0.56	0.46	0.09	0.98	0.82	0.16	1.54	0.11	1.30
2007	0.50	0.42	0.08	1.00	0.84	0.17	1.51	0.17	1.28
2008	0.42	0.35	0.07	0.84	0.70	0.14	1.26	0.16	1.10
Total	8.48	7.06	1.41	9.05	7.54	1.51	17.52	7.00	9.03
Annual	0.47	0.39	0.08	0.48	0.40	0.08	0.92	0.37	0.48

countries combined. The results provide further insights into the distribution of research benefits where some 83% of the benefits accrued to consumers, whereas only 17% of the benefits were captured by the producers. Since the cassava markets in the two countries are not well integrated and developed, there is limited commoditytrading or movement outside production zones. This implies that the producer households are largely the same as the consumer households hence the total welfare gains accrue largely to the same cassava producing households.

The cassava multiplication and distribution program was quite successful and worthwhile when evaluated on the basis of benefit-cost ratio and internal rate of return (IRR). Using a discount rate of 5%, the benefit-cost ratio was estimated at 3:1 and the rate of return for the program was found to be 24%. A benefit-cost ratio criterion recommends as viable any investment plan with a ratio-value equal to or greater than one. If the ratio is greater than one, the project is returning more benefits than it costs. The rate of return is the rate that equates NPV to zero and the higher the rate above the opportunity cost of capital the better the investment plan. The benefit-cost ratio of 3:1 suggests that the returns were three times higher than the research investment costs incurred. In other words, every dollar invested in the multiplication and distribution activities paid back three times through production gains associated with the use of CMD-free planting materials. The accrued benefits are taken as a measure of success and it can be concluded that the IITA/SARRNET cassava multiplication and distribution program has achieved reasonable success in Malawi and Zambia.

Potential economic impacts of cassava research and extension

New variety development

Early efforts to control the effects of CMD in Malawi and Zambia through the IITA-led SARRNET project focused on breeding cassava for disease tolerance. Several varietal trails conducted from early 1990s showed successes achieved in terms of developing high yielding and CMD tolerant varieties. So far, all the five improved varieties released in Malawi have a bitter taste and are only suitable for traditional cassava consuming areas such as along the lakeshore. In addition, it has been observed that some of the varieties such as *Mkondezi* were rejected by many farmers because of poor *Nsima* quality. Given the low and slow adoption of the first generation improved varieties due largely to lack of attributes valued by farmers, the focus for future work on

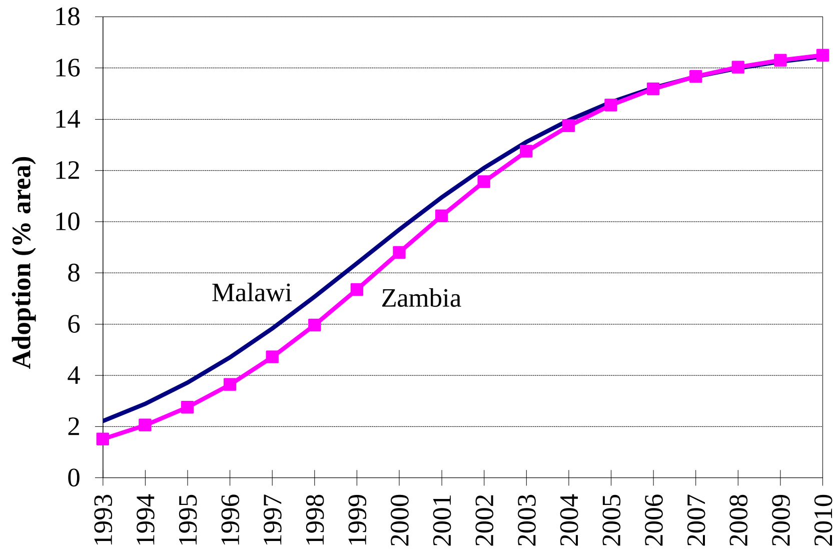

Figure 2. Adoption of CMD-free local cassava varieties in Malawi and Zambia.

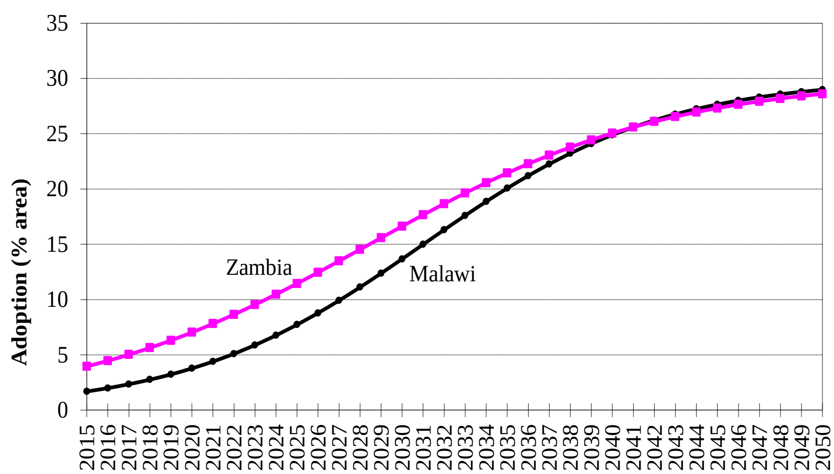

Figure 3. Projected adoption profile for new cassava varieties in Malawi and Zambia.

cassava research in the two countries should be on developing new varieties that are not only high yielding and CMD resistant but should also have consumption attributes highly valued by farmers who are also the major consumers of their own production. The other focus would be to enhance industrial characteristics in order to fast track industrial use and successfully catalyze the cassava commercialization process.

Expected adoption

If such line of cassava research succeeds in developing varieties with desired production and consumption characteristics, the adoption of the new cassava varieties is expected to be higher and faster in Malawi and Zambia, with an estimated adoption ceiling of 30%. On the basis of planting material production records and historical adoption rates of varieties preferred by farmers, expected adoption patterns for new varieties were projected using the logistic function for the period 2015–2050 (Figure 3). The economic surplus model for ex-ante analysis described earlier was used for the projection of potential impacts of cassava research that develops varieties with a range of characteristics preferred by farmers and other actors along the value chain.

Costs of variety development and dissemination

Estimation of net returns to cassava improvement research requires a comparison of the stream of benefits and the corresponding costs of the development and dissemination of improved cassava varieties. The research costs used in this analysis were adapted from previous and current cassava improvement activity budgets but were adjusted to cater for additional extension costs necessary to disseminate the new varieties upon release. The initial research costs were extracted from SARRNET project documents and are summarized in Table 2. Historical expenditures show that variety development accounts for 70% of the total cost, whereas variety dissemination accounts for the remaining 30%. The average annual expenditure for cassava research and extension in the SARRNET member countries was estimated at US$390,000 for twenty-three years until maximum adoption is attained. A total of US$8 million is estimated to be devoted to the development of the new varieties and dissemination of information to the farming families regarding their availability and potential benefits associated with the new varieties. As noted by Johnson et al. (2003), it is worth mentioning that when computing cassava research costs it is challenging to isolate breeding costs from other components of cassava improvement research investment.

Table 7 presents the net present value of potential economic benefits from cassava research and the corresponding estimates of the benefit–cost ratios and rates of return. The results show that, over the period 2015–2050, cassava research and extension can generate an estimated net benefit of US$97 million. This is equivalent to annual gross benefits of US$6 million for Malawi and US$3 million for Zambia following adoption of the new cassava varieties. The results also show nearly 85% of the benefits would accrue to the consumers and the remaining 15% go to the producers. Cassava research benefits are estimated to be higher in Malawi than in Zambia. International and national cassava research in Malawi and Zambia can have an impressive potential benefit–cost ratio of 21:1, indicating that each dollar invested in cassava improvement research generates US$21 worth of additional cassava.

Consistent with the payoffs implied by the estimated benefit–cost ratio, cassava research in Malawi and Zambia has the potential to generate a rate of return of 40%. The 40% internal rate of return to cassava improvement estimated for the two countries is much higher than the estimated rate of return to cassava research focusing on the multiplication and distribution of disease-free planting materials of the available farmer-preferred varieties such as Manyokola in Malawi and Muganga in Zambia. Furthermore, the estimated rate of return is much higher than the prevailing market interest rates and confirms that cassava research holds promise for generating a stream of benefits in excess of the expenditures. By all summary measures such as rate of return and benefit–cost ratios, the results suggest that benefits from cassava improvement are in excess of all cassava research costs in the region.

Sensitivity analysis

In an effort to gain confidence in the results, we evaluated the sensitivity of the base model estimates to variations in the values of some key parameters. Recognizing that the supply shift parameter is the major determinant of research benefits, the model was estimated with the proportional yield gains attributable to cassava research assumed to be half of the base yield gains. Given that the supply shift parameter is also a function of expected adoption of improved varieties, the model was estimated with the maximum adoption assumed to be 40%, up from the base value of 30%. The sensitivity of the estimated rate of return was also evaluated by estimating the model with research and extension costs assumed to be double the base value. The results of the sensitivity analysis presented in Table 8 show that, as a consequence of changes in supply shift, the present value of benefits is sensitive to changes in yield gains. Halving yield gains to about 20% has a proportional effect of halving research benefits to about US$46 million, but the rate of return drops only by 9 percentage points to 31%. On the other hand, raising the ceiling of expected varietal adoption from 30 to 40% has no proportional effect on net benefits and rate of return and has no effect on the benefit-cost ratio. More specifically, the net present value of benefits increases only by US$4 million and rate of return increases marginally from 40 to 42%, whereas the benefit-cost ratio remains the same as the base value of 21. Doubling of research and extension costs reduces net benefits by only 5% and the rate of return (to research and extension) also drops to 28%.

Overall, the summary measures suggest that the scenario with lower yield gains is the most conservative because it has a proportional effect of halving the net benefits to US$46 million as well as the benefit-cost ratios to 10. Similarly, the scenario with the research and extension costs double the base value has a comparable effect of halving aggregate benefit–cost ratio from 21 to 10 with a lower rate of return of 28%. The scenario with greater adoption of new varieties which reaches a maximum adoption rate of 40% before it stabilizes gives the highest rate of return of 42%. In general, the sensitivity analysis demonstrated that total net benefits from cassava research and extension in Malawi and Zambia vary between US$46 and 100 million and the benefit-cost ratio ranges from 10 to 21, with the rate of return varying from 28 to 42%. Although the sensitivity analysis lends credence to the main results, the minimum net benefits implied by the alternative scenarios are still an impressive US$46 million with a modest rate of return of 28% and benefit-cost ratio of 10.

CONCLUSION AND IMPLICATIONS

The national cassava improvement programs in Malawi

Table 7. Potential benefits of cassava research and extension in Malawi and Zambia.

Year	Malawi (US$ million)	Zambia (US$ million)	All (US$ million)	Net present value (US$ million)
2015	0.78	0.09	0.87	0.22
2016	0.92	0.15	1.07	0.35
2017	1.08	0.26	1.34	(0.28)
2018	1.27	0.43	1.70	1.06
2019	1.49	0.68	2.17	1.14
2020	1.74	1.05	2.79	1.48
2021	2.02	1.52	3.54	1.84
2022	2.35	2.05	4.40	2.15
2023	2.71	2.58	5.29	2.28
2024	3.12	3.03	6.14	2.93
2025	3.56	3.37	6.93	3.15
2026	4.05	3.60	7.65	3.26
2027	4.57	3.76	8.33	3.44
2028	5.13	3.85	8.98	3.52
2029	5.71	3.91	9.61	3.60
2030	6.31	3.94	10.25	3.66
2031	6.92	3.96	10.88	3.70
2032	7.53	3.97	11.50	3.71
2033	8.13	3.98	12.11	3.74
2034	8.72	3.98	12.70	3.74
2035	9.28	3.98	13.26	3.72
2036	9.81	3.98	13.79	3.68
2037	10.30	3.99	14.28	3.63
2038	10.75	3.99	14.74	3.57
2039	11.16	3.99	15.15	3.49
2040	11.53	3.99	15.51	3.41
2041	11.86	3.99	15.84	3.31
2042	12.15	3.99	16.13	3.21
2043	12.40	3.99	16.39	3.11
2044	12.62	3.99	16.61	3.00
2045	12.82	3.99	16.80	2.89
2046	12.98	3.99	16.97	2.78
2047	13.13	3.99	17.11	2.67
2048	13.25	3.99	17.23	2.56
2049	13.35	3.99	17.34	2.46
2050	13.44	3.99	17.43	2.35
Total	268.9	114.0	382.86	97.17
Annual	6.40	2.71	9.12	2.31
NPV (US$ million) = 97				
B:C ratio = 21				
IRR (%) = 40				

and Zambia have developed and released varieties that outperform the local varieties using breeding materials received from IITA. Past investments in cassava improvement have led to the development and release of a good number of high-yielding and CMD-tolerant cassava varieties. Over the period 1990–2011, IITA and the respective national programs released a total of 12 improved varieties in Malawi and 8 improved varieties in Zambia. The increased availability of improved cassava varieties opened up a range of profitable commercial opportunities for production of cassava-based foods, feeds, and industrial products. At the same time, improved

Table 8. Sensitivity analysis of the economic benefits of cassava research in Malawi and Zambia.

Parameter	Parameter value			NPV (US$ million)		IRR (%)		B:C ratio	
	Base	New	Δ (%)	New	Δ (%)	New	Δ (%)	New	Δ (%)
Yield gains (%)	0.40	0.20	-50	46	-47	31	-25	10	-50
Adoption ceiling (%)	30	40	33	101	4	42	5	21	0
Res. & Ext. costs (US$ m)	5	10	100	92	-5	28	-30	10	-50

disease tolerance and higher productivity as well as a flexible harvesting calendar offered prospects for improving household food security.

Despite major efforts to develop and disseminate a growing number of improved varieties, however, there is lack of comprehensive evidence on the adoption and economic impacts of improved cassava varieties. Using household survey as well as planting material production data for estimating variety adoption and on-farm experimental data for yield gains, this paper estimates the economic impacts of IITA-led cassava improvement research in Malawi and Zambia over the period 1990-2008. Historical as well as future adoption patterns were estimated using the logistic function with the minimum variety adoption data assembled from various sources. Consistent with the need for a gradual transformation of the scientific capacity of national programs, the content of earlier varietal releases points to the predominance of IITA germplasm supplied for direct release to farmers, whereas the content of recent releases shows that national programs are developing varieties using IITA material as a parent.

The results show relatively higher adoption rates for the CMD-free local varieties compared to CMD-tolerant varieties that have been released in the two countries. The adoption of new varieties has been low and slow largely due to the fact that most of these varieties lacked the consumption attributes highly valued by farmers. The multiplication and distribution of CMD-free planting materials of the recommended local varieties led to greater adoption, but infection with CMD three to four years after adoption meant that the yield gains and economic benefits could not be sustained. Nevertheless, the multiplication and distribution of clean cassava planting materials generated a modest rate of return of 24%, which is actually consistent with an earlier rate of return estimate of 9 to 22% for cassava improvement in developing countries. Analysis of the ex ante impacts of current and future investments in cassava research and extension shows that cassava research that focuses on the development and dissemination of varieties with highly preferred production, consumption, and industrial attributes would yield a greater rate of return of 40%.

Finally, it is worth noting that high rates of return to agricultural research are difficult to sustain in an environment where inputs are not accessible or affordable to farmers. A critical input for achieving greater adoption of improved cassava varieties is an efficient seed system for the production and distribution of highquality and disease-free planting material. Improved varieties can disseminate only with the help of an effective national seed industry, but this is still lacking in many countries in Africa especially for vegetatively propagated crops such as cassava.

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