IMPROVED MAIZE IN ZAMBIA: A QUALIFIED SUCCESS STORY*

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Maize is Zambia's most important crop. The need to provide Zambia's politically important urban population[1] with a dependable source of cheap food, and a desire to improve small farmer incomes, motivated considerable investment in maize varietal research by the government of Zambia (GRZ) and other organizations beginning in the late 1970s. These investments led to the release of ten improved hybrids and open-pollinated varieties from 1984-88.

This paper examines the impact of these research investments, hypothesizing that the spread of the new technology was integrally linked to concurrent investments in extension, the seed industry, marketing and price policies that critically influenced farmer adoption decisions. The first section describes the agroecological environment and sketches the development of improved maize varieties in Zambia. Evidence from a recent field study of improved maize adoption and the average rate of return (ARR) to maize technology investments is presented in the second section. Section three analyzes the effect of price and marketing policies on maize technology adoption and the ARR, outlining results from a numerical simulation of adoption under a counterfactual without-policy scenario.

1.0. Maize technology development in Zambia

1.1. Agroecology and farming systems

In much of southern Africa, including Zambia, colonization introduced modern commercial large-scale farming systems that evolved alongside the traditional small-scale systems. Today, there are three major categories of farmers in Zambia. Small-scale or traditional farmers cultivate less than five hectares and consume most of their produce, using mainly hand hoes and few external inputs. Seventy-five percent of Zambia's 600,000 farm households are small-scale, working more than 60 percent of the total cropped area. Medium (5-20 hectares) and large-scale farmers (over 20 hectares) use improved seeds and fertilizers, make use of animal draft power and

[1] Zambia is one of sub-Saharan Africa's most highly urbanized countries; over 50 percent of the total population of nine million lives in cities (World Bank 1993). Urbanization is linked to the historical predominance of copper mining, rather than agriculture, in Zambia's economy.

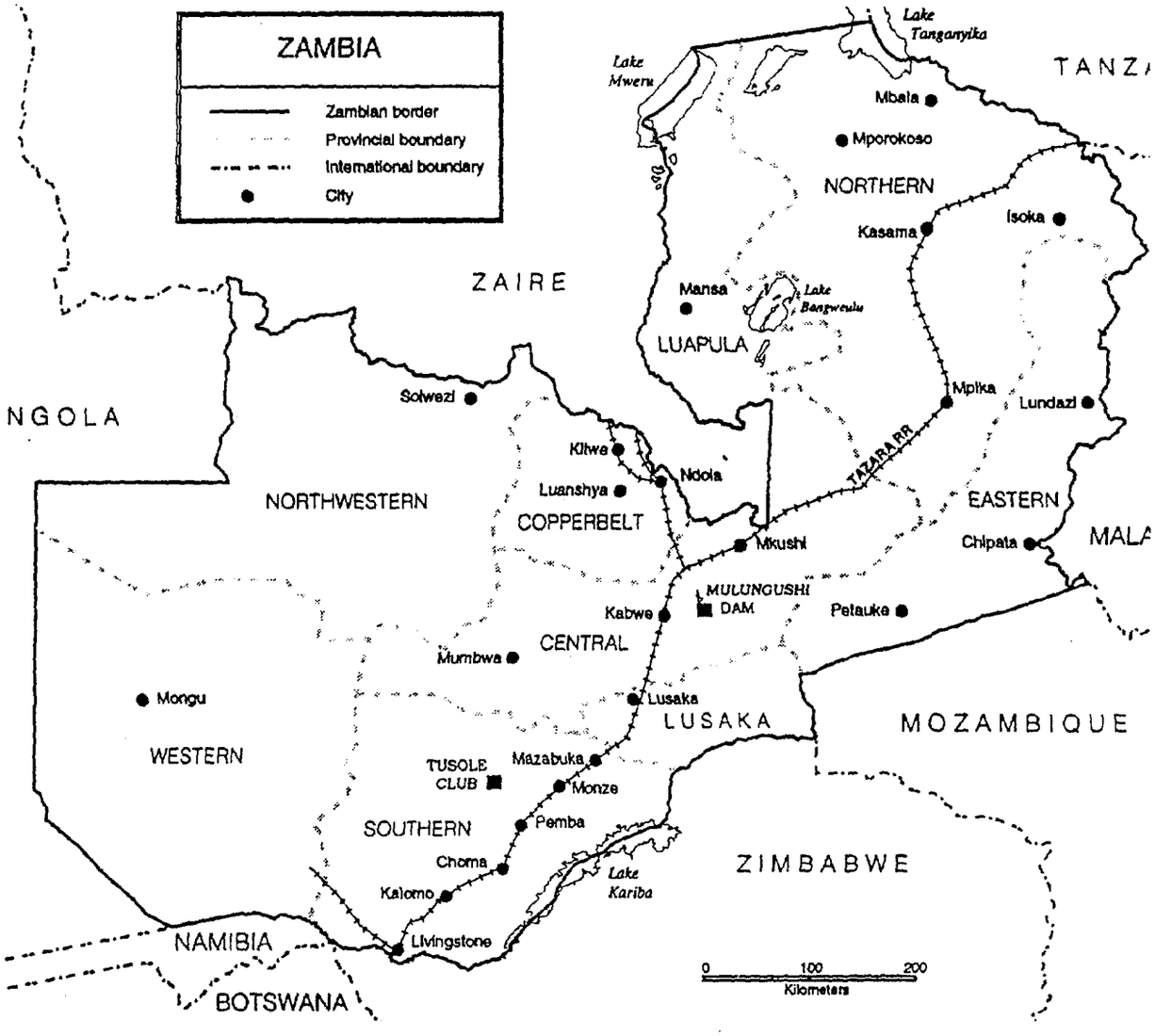

Figure 1: Map of Zambia

tractors, and sell most or all of their production (World Bank 1992, 8; GRZ, 1991, 19).

Zambia is located in the savanna ecological zone, and subdivided into three major agroecological regions (Figures 1,2). Rainfall varies from under 700 mm annually in the southern Zambezi valley near the Zimbabwean border in Region I, to over 1400 mm in parts of Northern Province and Region III. Region II's annual rainfall (800-1000 mm/year) and clayey to loamy

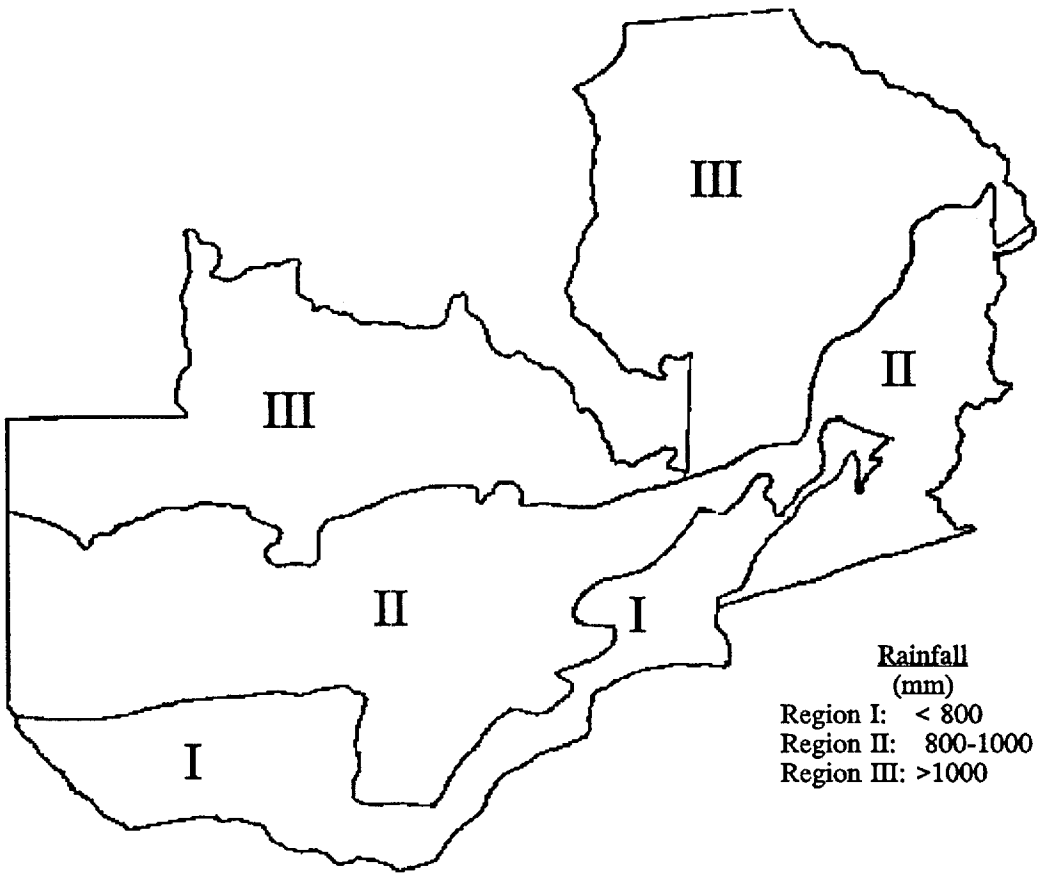

Figure 2: Agroecological regions

soils are most favorable for maize production, and it is home to most medium and large-scale farmers. Region II lies in a band across central Zambia, close to major urban markets for maize in Lusaka and the Copperbelt.

In contrast to other countries in sub-Saharan Africa, including Malawi, the majority of Zambia's arable land remains uncultivated. Only about 2 million of an estimated 9 million hectares of arable land are cropped or lying fallow (GRZ 1991, 37).

1.2. Maize varietal improvement in Zambia[2]

Before independence, Northern Rhodesia relied on its Federation partner Southern Rhodesia for maize seed. Southern Rhodesia had a maize breeding program as early as 1933. Its spectacularly successful SR52 was released in 1960 and widely adopted throughout Southern Africa. SR52 is a tall white dent[3] with large ears, and has a long season, taking 160-165 days to reach maturity (Eicher 1994; Zamseed 1987).

In Northern Rhodesia, large-scale European commercial farmers were the primary users of SR52 and other improved varieties imported from Southern Rhodesia. Small-scale farmers, who could not afford inputs or meet the higher management requirements, usually planted "local" maize varieties. "Locals" are open pollinated, long-season varieties, requiring lower levels of management than the imported hybrids and open-pollinateds. They are flinty and have small grains as opposed to the large, denty hybrid grains. Over time, the distinction between "importeds" and "locals" has blurred as maize in small-scale farmers' fields became cross-pollinated with improved maize from neighboring commercial farms, especially Hickory King (McPhillips, personal communication, July 9, 1991; Gibson, personal communication, March 12, 1993).

1.2.1. The Zambian breeding program

Zambia's maize breeding program was initiated in 1965 with the arrival of J.B. Abington, partially supported by British ODA. Abington's principal objective was to produce varieties that

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[2] This section draws on Howard, Kalonge, and Chitalu (1994), **Improved maize in Zambia: a biography**.

[3] The texture of maize grain ranges from hard (flint) to soft (dent). "Dent" maize has a characteristic depression in the top of the kernel which comes from the proportion of hard or vitreous endosperm in the kernel to the soft or floury endosperm. The "dent" is formed because the soft endosperm collapses inwardly as the kernel dries. Local or unimproved maize in Zambia tends to be flinty, and improved hybrids are more denty. Flinty maize appears to store better than dent types, as the harder grain is more difficult for insects and microorganisms to penetrate (Blackie,5-6).

would be higher yielding and better suited to the needs of small farmers in different agroecological zones than SR52, and the other popular hybrids from Southern Rhodesia, SR13 and SR11, (Ristanovic et al., 1985). Four varieties and one hybrid were developed during his tenure (ZCA, ZUCA, ZYC, ZSC, ZH1), but never proved very popular, partly because their growing seasons were still quite long and yields were inferior to SR52 (personal communication, Chibasa, Oct.30, 1992; World Bank 1983, 27).

When Abington left Zambia in 1973, an ODA-supported agronomist/breeder, Mr. Bradwell, took over Zambia's fledgling maize breeding program until 1976. The breeding orientation shifted from quantitative (yield improvement) to qualitative factors such as protein quality, cytoplasmic male sterility, dwarf brachytic genes and testing foreign hybrids and varieties for agronomic suitability (Mwale 1987).

Yugoslav involvement in maize research stemmed from a 1974-5 visit by then President Kaunda to Yugoslavia. Dissatisfied with the lack of progress in the Zambian program, and visibly impressed by the maize crop around Belgrade, Kaunda reportedly asked his friend Marshal Tito for assistance. An agreement was reached in which the Yugoslav Maize Research Institute (MRI) would be allowed to use a farm near the town of Mazabuka as a winter nursery site. In return, MRI would send a maize breeder to work with the Zambian program, and Zambian maize and sunflower researchers would also be trained on-site and in Yugoslavia (McPhillips, personal communication, Oct. 28, 1992; Chibasa, personal communication, Oct. 30, 1992).

C. Jovanovic, the first maize breeder sent by MRI to assist the Zambian program, arrived in 1977. The following year, the first Zambian professionals joined the maize breeding program, both with Bachelor of Science degrees from the University of Zambia School of Agriculture.

Jovanovic brought many CIMMYT populations to Zambia for testing and improvement, and was keenly interested, like Bradwell, in the development of high-lysine maize.

At the same time, another Yugoslav, D. Ristanovic, began work as the senior maize breeder at the MRI winter nursery farm near Mazabuka. Ristanovic also brought germplasm to Zambia, primarily South American and African in origin, from the collections of the Yugoslav Gene Bank. When Jovanovic was involved in a serious car accident that necessitated his early return to Yugoslavia, Ristanovic was asked to substitute temporarily in the Zambian program; eventually the transfer was made permanent. Thirteen years later, he remains with the Research Branch (Ristanovic, personal communication, Oct. 11, 1992).

Soon after he arrived in Zambia, Dr. Ristanovic began to notice the lack of uniform height and unusual morphological variation in the most widely planted hybrid, Zambian SR52[4], although hybrids are expected to be uniform in height and other characteristics. Contamination of both parents of SR52 occurred because of improper maintenance of the breeder's seed, resulting in a yield loss of about 15 percent in the Zambian SR52 compared to the original Rhodesian/Zimbabwean version (Ristanovic et al., 1985).

Efforts to obtain the original parents from Zimbabwe failed, so Ristanovic started cleaning both parents in the 1977-78 season, completing the work in 1978-79. Additional testing of the newly purified SR52 was conducted during 1980-81 and 81-82 at five locations countrywide and showed a yield increase of 20 percent over the old SR52, although this was not statistically significant. The new version, the first of the Zambian improved varieties examined in this study, was released in 1983 under the name Mount Makulu 752 (MM752), with "52" retained to show the connection to SR52 (Ristanovic et al., 1985).

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[4]After independence, breeders began producing a Zambian version of SR52 from the parent lines instead of importing SR52 from Southern Rhodesia.

1.2.2. Improved maize for small farmers

It was clear to Zambian policymakers by the 1970s that the key to increased maize production lay with the small farmer, and the price and marketing policies being carried out by GRZ already reflected the greater emphasis on drawing small farmers into commercial maize production. Developing new maize technologies that were better adapted to small farmer needs was a logical next step.

Perhaps the most serious problem confronting small farmers interested in planting commercial maize varieties like SR52 was the long growing period that required early planting. Zambian small farmers tend to plant commercial maize late for several reasons. If they are using hand hoes, it is extremely difficult to prepare the fields before the first rains have softened the very hard surface. Also, if farmers hoe early in the season, fields must be weeded a second time later on. Farmers usually wait to plant commercial maize until after local maize and the other family subsistence crops have been planted, but this has a high cost. Late planted maize is vulnerable to maize streak virus, especially in wetter areas such as Region III. More important, researchers estimate that farmers lose 1-2 percent of maize yield for each day of delay (Gibson, personal communication, March 12, 1993).

Small farmers required maize seed that was shorter-season and better adapted to conditions in the different agroecological regions. In the late 1970s, a key question was the suitability of open-pollinated vs. hybrid varieties for small farmers. Unlike many other countries in sub-Saharan Africa, in Zambia a unique set of conditions combined to create an environment that facilitated the adoption of SR52 by small farmers, then made further development of improved hybrids possible.

Improved open-pollinated varieties like Hickory King were already being promoted through extension programs such as the peasant farming scheme in the 1950s. Adoption of SR52 in

combination with fertilizer use was the focus of the extension service's Lima program during the 1980s. Through these early programs small farmers learned about the yield advantage they could obtain by using hybrids with fertilizer instead of local open-pollinated varieties. SR52's yield was estimated to be 46 percent greater than the improved open-pollinated variety Southern Cross in Zimbabwe (Eicher 1994, 11). The expansion of parastatal marketing outlets and credit programs made it easier for small farmers to obtain purchased inputs and market surplus maize.

At the beginning of the 1980s SIDA was starting to fund maize research, and at the same time helping to establish a Zambian seed industry. It was obvious from the start that maize seed would be the most important product. Maize seed represented 70-90 percent of the total volume of Zamseed's sales in the late 1980s (SIDA 1988, 63). To ensure the new company's viability, Zamseed and its technical advisers at Svalöf in Sweden pushed for the development of hybrids, for which new seed would be purchased each year, rather than open-pollinated varieties whose seed could be saved and replanted.

SIDA's assistance to the maize research program included taking over the payment of Ristanovic's salary and operational support. Ristanovic, through his graduate education in the U.S. and work experience as a senior breeder in the Yugoslav Maize Research Institute, was focused on improvement of hybrid maize, convinced that the real opportunities for yield improvement lay in hybrids, not open-pollinated varieties, even for small farmers. Beyond the purification of Zambian SR52, Ristanovic and his counterparts sought to develop new hybrids and varieties that were earlier maturing, more drought tolerant and more disease resistant than MM752.

As a result, seven shorter-season hybrids were developed and released between 1984-88 (Table 1). The new varieties had shorter seasons than SR52 or MM752 by as much as 35 days. In all but the most adverse environments, hybrid maize outyielded open pollinated locals and (later)

improved open pollinated varieties even when no fertilizer was used (personal communication, Gibson, Oct. 1993). Unlike the single crosses SR52/MM752, several of the newer hybrids were double or three-way crosses, which made their yields much more stable if farmers planted second generations, although this was never recommended. The average yield loss when SR52 was replanted was about 33-43 percent, but for advanced generations of MM603/604 it was only 15-20 percent (Norrby 1986; Gibson and Ristanovic 1985, 2).

Ristanovic developed a close working relationship with Zamseed professionals, in part because funding for the hybrid maize program's operating expenses was channeled through the seed company. Ristanovic later described himself as an "entrepreneur" in his dealings with Zamseed, selling and shaping a product for a market. One result was the rapid availability of the new hybrids through Zamseed following their release from the breeding program. Another was a heavy emphasis on MM603/604, a triple cross hybrid for which seed could be produced cheaply, and widely adaptable across Zambia's agro-ecological regions. Several other releases were single or double crosses of one or more of the parents of the MM603/604, making seed production simpler and more economical (personal communication, D. Ristanovic, November 9, 1992).

SIDA-funded researchers cooperated with the USAID-funded ZAMARE maize team, informally agreeing that Ristanovic would continue to concentrate on hybrid breeding, while the principal maize breeder assigned to ZAMARE, Paul Gibson, focused on open-pollinated maize. Two open-pollinated varieties, streak-resistant MMV 600 and the extremely short-season flinty MMV 400, were released in 1984. Gibson saw a place for both hybrids and open-pollinated varieties in Zambian farming systems, and acted as an intermediary between "camps" of those who felt hybrids were not appropriate for small farmers and Ristanovic's team. He established close

Table 1: Characteristics of Zambian maize hybrids and varieties

Type and year released	Days to maturity	Yield in tons/ha	Target area	Characteristics
MM501 1984	130-135	6.0	Regions I, II	Single cross, white semi-dent; drought tolerant; mod. resistant maize streak virus (MSV), rust, blight, cob rot
MM502 1984	140-145	7.5	Regions II, III	Single cross, white semi-dent; multiple cobs; high resistance MSV; mod. resistance blight, cob rot
MM504 1984	135-140	6.5	Region I	Three-way cross, white dent; drought tolerance; good resistance lodging; mod. res. MSV, rust, blight, cob rot
MM601 1984	140-145	7.5	Regions, II, III	Single cross, white semi-dent; mod. drought tolerance; resistance blight, rust, MSV, cob rot
MM603/604 1984	145-150	7.0	Regions II, III	Three-way cross, white dent; multiple cobs; high resistance MSV, resistance blight, rust, cob rot
MM752 1984	160-165	8.0	Regions II, III	Single cross, white dent; susceptible lodging, MSV; mod. resistant rust, blight
MM612 1988	155-160	7.0	Regions II, III	Double cross, white dent; resistant MSV
MMV600 1984	150-160	4.0-5.0	Regions I, II, III	Open-pollinated, white flint; resistant lodging, rust, blight, MSV
MMV400 1984	120-125	2.5-3.5	Region I	Open pollinated, white flint; resistant blight

Sources: Zamseed Maize Production Guide; Ministry of Agriculture, Food and Fisheries Guide to Commercial Crop Production; D. Ristanovic, personal communication, 1992

[a] Research station yields under medium levels of management.

links with the provincial ARPTs (Adaptive Research Planning Teams) and was instrumental in ARPT testing of the new hybrids as well as the open-pollinated varieties, and in promotion of the new hybrids among commercial farmers

Although a possible niche for open-pollinated varieties existed in the commercial market, it was difficult to motivate farmers to use them after they had tried the hybrids with fertilizer and realized impressive yield gains. As long as the expectation of input delivery was there, because of the presence of the local cooperative depots, farmers took the chance, consciously or because their credit packages tied them to cooperative-delivered input packages.

2.0. Technology adoption and the rate of return to investments in maize research and dissemination

2.1. Technology adoption

Adoption of improved maize varieties by Zambian farmers was rapid and extensive following their release in 1984-8. Results from a survey of 460 small and medium-scale farmers in Zambia's major maize-growing areas[5] indicated that by 1991-92, 60 percent of maize area in Zambia -- three-quarters of maize area in Region II, 40 percent in Region III, and 25 percent in Region I -- was planted to improved varieties (Figure 3). The increase in overall maize yields resulting from adoption of improved varieties was estimated at 20 percent.

A striking proportion of improved maize adopters had used fertilizer at least once, 88 percent of small and 97 percent of medium farmers, and fertilizer application rates for maize are the second highest in Africa (CIMMYT 1990). In addition, 64 percent and 90 percent of small and medium adopters had sold maize; 42 percent and 68 percent had received credit for maize, and 47 percent and 58 percent had been visited by an extension agent. The dependence of small and medium farmers on local, as opposed to regional, depots is an indication of how widespread and

[5] For details about the survey and further results, see Howard (1994).

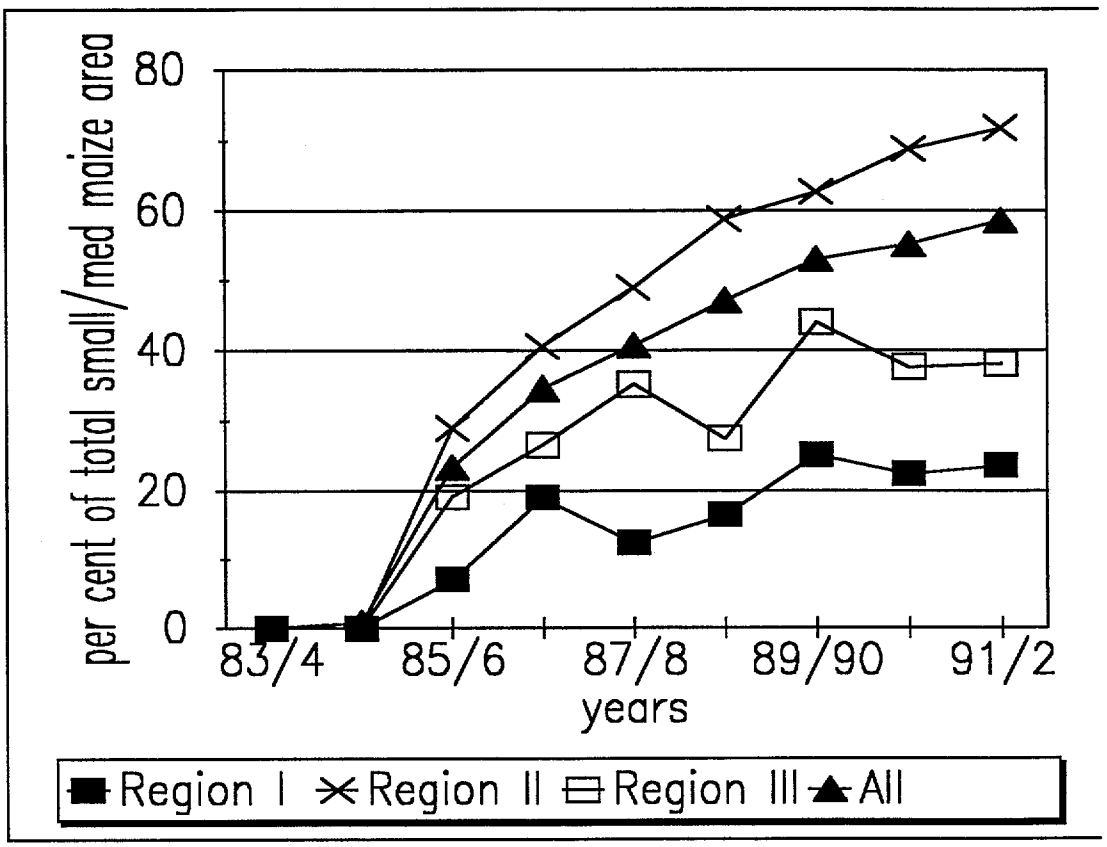

Figure 3: Adoption of improved maize 1984-92

localized service provision became throughout Zambia's maize-growing areas. 82 percent of improved maize users got their fertilizer at local depots, 86 percent sold their maize there, and 80 percent purchased maize seed locally.

The quality of government-supported services declined in the late 1980s, and, together with rising fertilizer prices and declining real maize prices, diminished incentives for growing maize in

outlying areas. After 1989/90, the proportion of small/medium maize area planted to improved varieties levelled off and declined slightly in Regions I and III, while continuing to grow in Region II. The diminishing ability of the government to finance and coordinate maize-related services was reflected in the decreasing availability of credit and fertilizer, and persistent and worsening delays in input delivery and payment for maize, especially in Regions I and III.

2.2. Production changes

Following the introduction of improved Zambian maize, maize production more than doubled, from 930,000 tons in 1983-84 to nearly 2 million tons in 1988-89, before falling off more recently. Maize area increased from 564,000 to 797,000 hectares in the same period (Figure 4). Figure 4 shows production in the mid and late 1980s as the higher of two pyramids of maize production in the 1970s and 1980s.

2.3. Average rate of return to research and complementary investments

Survey results support the hypothesis linking adoption of improved technology to complementary investments in marketing and price policies, the seed industry and extension. The earlier 1970s production boom coincided with the beginning of fertilizer subsidies, expansion of marketing facilities and the Lima Program, suggesting that complementary investments were also important in past farmer adoption of SR52 plus fertilizer. Poor weather and fertilizer shortages in the late 1970s brought a sharp decline in production. Since the array of non-research services provided mainly by the government is assumed to have shaped the impact of research, i.e., technology adoption, an economic rate of return was calculated for the whole package of maize investments, and contrasted with the rate of return resulting when the costs of some programs are excluded, as in most studies of research impact[6].

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[6] See Howard (1994) for details of the rate of return calculation

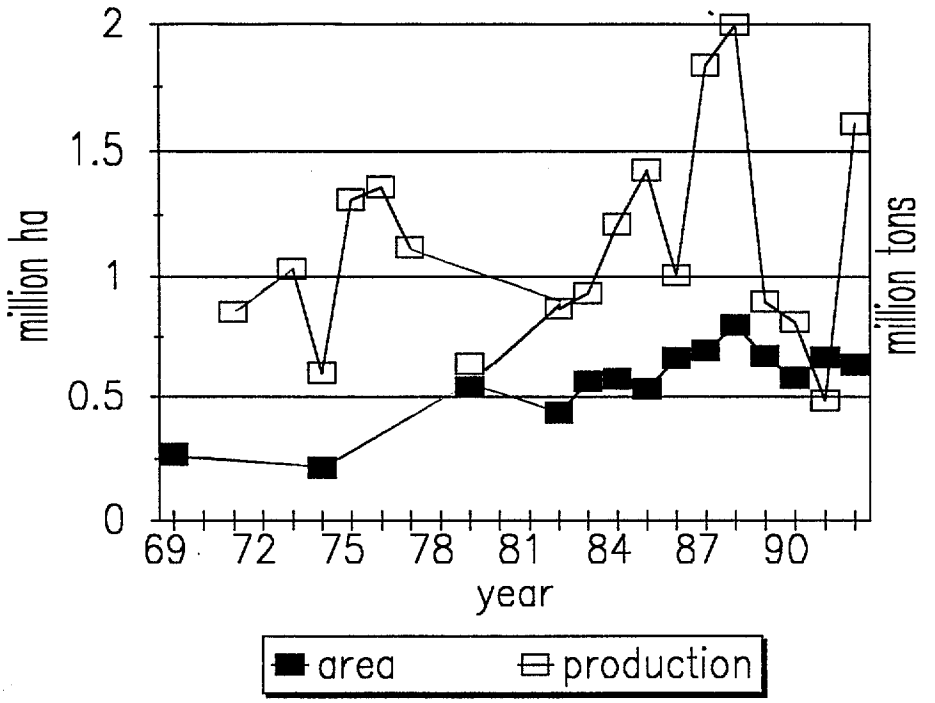

Figure 4: Maize area and production, 1978-92

Benefit-cost and index number approaches (BCI) was used to calculate an average rate of return (ARR) to the set of investments in maize research, extension, the seed industry and marketing organizations during the 1978-91 period, and a projected ARR for 1978-2001. Benefit-cost analysis compares the values of the "with project" and "without project" environments. If "with" exceeds "without" the project(s) is judged a potential Pareto-improvement (Randall 1987, 234-5). The "without" scenario represents a projection of what would have happened in the absence of program investments. Here, the "without" case assumes continued availability of local, SR52 and non-Zambian varieties, but no fertilizer for small/medium farmers.

Figure 5 shows the "with" and "without" scenarios graphically. The impact of aggregate investments in Zambian maize research, extension, seed and marketing is a nonmarginal increase in the supply of maize, represented by the outward shift of the supply curve from S (without) to S′ (with). The total change in economic surplus resulting from investments in the maize sector is approximated by the algebraic sum of gains and losses to consumers and producers, or P_nBAP_0-P_nB0+P_0A0.[7] The net change is approximately 0BA. The additional economic surplus created by the outward shift in the supply curve represents the gross benefits arising from investments in maize research and related investments. To estimate the ARR, net benefits for each year or other relevant time period were calculated by subtracting program expenditures from the gross benefits, here the value of additional production, for that period. The ARR is the discount rate that just makes the net present value of the net benefit stream equal zero.

Four steps were followed to convert financial market prices to their economic values: (1) estimating the shadow exchange rate; (2) establishing what proportion of costs represent tradeable items; (3) converting that amount to local currency terms using the shadow exchange rate; and (4) estimating the import parity price for maize and other commodities such as fertilizer and seed

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[7] The approximation formulas derived by Akino and Hayami for estimating P_nBCP_0, ABC, A0C are:

$$P_nBCP_0=P_0Q_0\frac{K(1+e)}{e+n}[1-\frac{\frac{1}{2}K(1+e)n}{e+n}-\frac{1}{2}K(1+e)n]$$

$$ABC=\frac{1}{2}P_0Q_0\frac{[K(1+e)]^2}{e+n}$$

$$A0C=KP_0Q_0$$

$$ACQ/_nQ_0=(1+e)KP_0Q_0$$

where K=shift in the production function; [(1+e)K] approximates the shift in the supply curve.

whose market prices are significantly altered by government policies, and substituting the import parity price for the market price in the economic analysis.

Expenditures included were the economic values of (1) additional production costs incurred by farmers when they adopted the new maize variety or when fertilizer became available to small farmers; (2) maize-related research and seed industry expenditures incurred by the Ministry of Agriculture, Food and Fisheries (MAFF) and international agencies since 1978 for salaries, general operating overheads and operating expenses; (3) maize-related expenditures from 1978 by MAFF and international agencies for extension staff salaries and overheads, operating expenses for maize-related extension programs such as Lima, radio extension programs; and portions of integrated rural development programs that included maize technology dissemination as a major element; (4) marketing expenditures since 1978, including staff and operating expenses of the GRZ Department of Cooperatives and Marketing, subsidies to Namboard, the Cooperative Unions and millers for input and maize marketing, milling, and consumer price subsidies, and expenditures by SIDA in support of cooperative development, including training, construction of marketing sheds and other infrastructure, and technical assistance.

Some maize subsidies paid by the government or donors, such as those used to establish and maintain the cooperative marketing system, were included as program costs, since they represented an expenditure of resources required in order for the whole maize program to operate. Other subsidies, such as the price differential subsidy paid to Namboard and the cooperative unions to cover the difference between the purchase and selling price of maize, were considered to be direct income transfers rather than a cost of production or marketing leading to a change in national income, and thus were excluded from the economic analysis (Gittinger 1982, 19, 50).

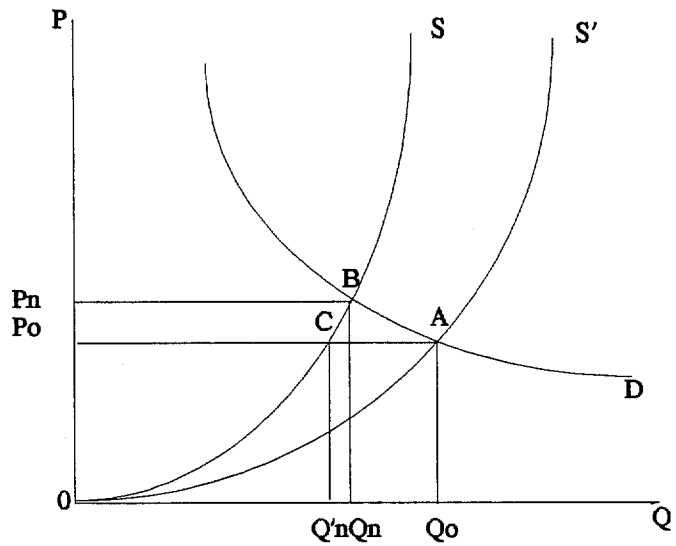

Figure 5: Supply shift from research and related investments

The ARR was calculated using both index number (Akino-Hayami) and benefit-cost approaches. A summary of results is presented in Table 2. Rates of return were calculated for two periods, 1978-91 and 1978-2001 (projected), under a variety of cost scenarios.

When all costs were included in the analysis (additional production costs associated with the new technology, and maize-related costs of research, extension, seed industry and marketing) the ROR for the 1978-91 period was negative for both the benefit-cost and Akino-Hayami methods of calculation. Extending the analysis period to 2001 resulted in a positive ROR of 49.3 percent using the cost-benefit method, and 42.1 percent using the Akino-Hayami approach. The critical

difference is the assumption that GRZ expenditures on maize marketing drop sharply after 1992, according to the new government's plan to completely liberalize the sector.

When marketing costs were excluded from the calculation, the rates of return were sharply positive. Using benefit-cost analysis, for both the 1978-91 and 1978-2001 periods, RORs are all in excess of 200 percent. RORs generated using the Akino-Hayami method were slightly lower. For the 1978-91 period, RORs ranged from 99.2 percent when all costs except marketing were included, to 113.9 percent, when only production and research costs were included. For the longer period 1978-2001, RORs ranged from 103.5 percent to 116.6 percent.

The Zambia results illustrate the danger in evaluating the impact of research in isolation from complementary support programs. If the common assumptions for ROR to research studies are adopted, and only additional production and research costs are counted, the resulting ROR is extremely high, from 113.9 percent to over 200 percent. This compares very favorably with RORs calculated for research alone in other African countries. Cocoa research in Nigeria had a return of 42 percent (Abidogun 1982), the ratio of benefits to costs of African cassava pest research was 149:1 (Norgaard 1988), and Evenson (1987) estimated that the overall ROR to investments in maize and staple crop research in Africa from 1962-80 was 30-40 percent. Looking at the Zambian ROR, the conclusion would be that investments in maize research have been a tremendous economic success.

The picture changes completely when the costs of all complementary organizations are included in the analysis. For the 1978-91 period, the ROR is negative, suggesting that the general maize development program was uneconomic. In fact, the unsustainability of the maize marketing program, which by the late 1980s consumed almost 17 percent of the total government budget

resulted in its near total phaseout after the Chiluba government came to power in late 1991(GRZ 1990, 15).

Basing policy recommendations on the ROR to research programs in isolation from the effects and costs of complementary organizations risks missing critical issues. One concern is how

Table 2: Summary of results, economic rate of return (ARR) analysis

(percent)

	Benefit-Cost Method		Akino-Hayami Method	
Average rate of return	1978-91	1978-2001	1978-91	1978-2001
Including all costs (additional production, research, extension, seed, marketing costs)	negative	49.3	negative	42.1
Including additional production, research costs only	200+	200+	113.9	116.6
Including additional production, research, extension costs only	200+	200+	101.8	105.8
Including additional production, research, extension and seed costs only	200+	200+	99.2	103.5

dependent the success of the research investment is upon simultaneous investments in related organizations, and their associated costs. The second issue is allocative efficiency, the impact of investments in one sub-sector upon the efficiency of other sub-sectors. A recent distortion coefficient analysis (World Bank, 1992) confirms that the impact of government policies over the last two decades has been to skew incentives toward maize production. Domestic resource cost

estimates show that Zambian smallholders have the potential to expand production of many other crops besides maize profitably (World Bank 1992).

3.0. The impact of policy interventions on returns to investments in research

Because it was the cost of marketing policies that made the ARR negative in the 1978-91 period, production under a counterfactual "without-policy" scenario was numerically simulated to estimate the ARR and distribution of benefits from new technology in the absence of marketing policies. Beginning in the 1970s, Zambia's government consciously implemented policies that brought farmers in the poorer, more remote Regions I and III, as well as more isolated areas of Region II, into commercial maize production for the first time. These policies -- pan-territorial, pan-seasonal pricing, and locally available credit, input and product marketing services-- were implemented by channeling subsidies through Namboard and the cooperative system. The dual objectives of this strategy were to (1) ensure and increase the supply of maize to the politically important urban centers, and (2) reduce the widening disparities in the society, in income and future development possibilities, that resulted from copper-led development and the concentration of agriculture along the rail corridor since colonial days. Political interest also motivated the extension of services to more remote rural areas; many leaders of Kaunda's UNIP Party came from Eastern Province (Bates and Collier 1993).

During the 1970s and 1980s, as a result of these policies and improving technology, the pattern of maize production changed. The small and medium-scale share of production rose from 60 to 80 percent (GRZ 1990, 34), and the proportion of maize coming from remote provinces such as Northern and Eastern grew, while that from line-of-rail provinces, Central and Southern, declined.

To simulate a without-policy scenario, Zambia was disaggregated into eleven sub-regional analysis areas. The impact of research on production and distribution of benefits in the absence of price and marketing policies was simulated for each area using primary and secondary data. The sub-regional results were later aggregated to the national level and used to estimate a revised ARR in the absence of policies, and the distribution of benefits in the with and without policy cases. 1987-88 was selected as the target year for simulation, since it was a year of average weather conditions for maize, when government supply of complementary services was still relatively good.

The expansion of production in Zambia between 1987-88 (without policies, technology) and 1987-88 (with policies, technology) can be seen as a series of consecutive rightward shifts of the supply curve, intermediate between S and S′ (Figure 5). In Zambia, there were four main factors which acted to shift the supply curve: (1) adoption of SR52; (2) adoption of other Zimbabwean hybrids such as R201 and R215; (3) adoption of Zambian hybrids; and (4) policies of the Zambian government, including pan-territorial pricing of maize and fertilizer, and support for the system of marketing depots in rural areas operated by the parastatal marketing board together with the cooperative system.

3.1. S_0

Separate supply curves were constructed for the base (without-policy) situation and each "shift." These are shown in Figure 5 as S_0, S_{SR52}, S_{Zimb}, S_{Zam}, and S_{Pol}. Quantities supplied under each technology, at the prevailing with or without policy price, were estimated as Q_0, Q_{Sr52}, Q_{Zimb}, Q_{Zam} and Q_{Pol}. S_0 represents estimated 1987-88 maize production in the absence of improved maize varieties and policies. For S_0, it is assumed that large and small/medium farmers continue to use the technology prevailing in 1971-72[8]; production estimates are brought forward to 1987-88

[8] The 1971-72 season was used as a base year because it was the last season before significant government marketing policies affecting small farmers were put in place.

by assuming that farmers in a given area continue to produce for domestic consumption and export needs in the same proportions in 1987-88 as they in 1971-72. For example, if in 1971-2 farmers in Area Z produced enough for Area Z's consumption needs and exported 1.5 times the amount consumed locally, it is assumed that in 1987-88 these farmers would also have supplied domestic needs (accounting for population growth) and continued to export 1.5 times this amount outside Area Z.

$S_0 = a_I P^e$
where
a_I=scale parameter
P=maize price received by farmers in the absence of policies
e=price elasticity of supply

The prevailing technology in 1971-72, and therefore in the "without-policy" 1987-88 scenario, differs for large and small/medium farmers. Large farmers are assumed to have easy access to both SR52 and fertilizer, and to fertilize maize at full recommended levels. Small/medium farmers are assumed to use only local maize varieties and no fertilizer, although in reality a few would have used these inputs even without government programs.

In the numerical simulation, Q_0 is the estimated maize production in a given area under the "without policy and technology" conditions detailed above. This amount is projected from actual production in 1971-72, adjusted for population but maintaining the ratio of domestic production to exports observed in 1971-72. The producer price for maize in the absence of policies, P, is the import parity price for areas where maize is traded, and the estimated local market price in autarkic areas. The import parity price is used because Zambia has been a net maize importer in most years since 1970.

The estimates of supply and demand elasticities used (e, n) throughout the analysis, for all areas, are .65 and .10, respectively, based on estimates by Harber (1992) and Nakaponda (1992). a_I is a scale parameter derived after substituting the numerical values for all other parameters.

3.2. Estimation of S_{SR52}

$S_{SR52} = (1+h_{SR52})a_I P^e$
where h_{SR52}= the rate of shift in the supply function due to adoption of SR52;
$h_{SR52} \approx (1+e)k_{SR52}$;

and k_{SR52} = the proportion of maize area planted to SR52*(yield increase of SR52 over local varieties) / yield of local varieties[9]

S_{SR52} is the increased production resulting from the availability of SR52 to small/medium farmers. h_{SR52} represents the rate of shift in the supply function due to the adoption of higher-yielding SR52. It is assumed that small/medium farmers using SR52 do not use fertilizer. h_{SR52} is approximated by $(1+e)k_{SR52}$; k_{SR52} is estimated by calculating the yield increase of SR52 over local varieties, weighted by the average small/medium area under SR52. This area was estimated from MSU/MAFF/RDSB Maize Adoption Survey data. Respondents gave a detailed description of their cropping patterns beginning the year before adoption of improved Zambian maize varieties. Cropping patterns from the year before adoption were taken to represent cropping patterns of both adopters and non-adopters. These responses were pooled to get the average area under SR52 in each sub-regional analysis area prior to the availability of Zambian improved maize varieties.

3.3. Estimation of S_{Zimb}

$S_{Zimb}=(1+h_{Zimb})(1+h_{SR52})a_tP^e$
where h_{Zimb}=the rate of shift in the supply function due to adoption of Zimbabwean hybrids;
$h_{Zimb} \approx (1+e)k_{Zimb}$;
and k_{Zimb} = the proportion of maize area planted to Zimbabwean hybrids * (yield increase of Zimbabwean hybrids over local varieties) / yield of local varieties

S_{Zimb} is the increased production resulting from the availability of (non-SR52) Zimbabwean hybrids to small/medium and large farmers. h_{Zimb} represents the rate of shift in the supply function due to the adoption of Zimbabwean hybrids. It is assumed that small/medium farmers using Zimbabwean hybrids do not use fertilizer, but large farmers apply the full recommended levels. h_{Zimb} is approximated by $(1+e)k_{Zimb}$; k_{Zimb} is estimated by calculating the yield increase of Zimbabwean hybrids over local varieties, weighted by the average small/medium and large farmer area under Zimbabwean hybrids. Large farmer area was estimated from responses to the MSU/MAFF/RDSB mail-in survey of large farmers. Small/medium area under Zimbabwean hybrids was estimated from MSU/MAFF/RDSB Maize Adoption Survey data in the same way as described above for

[9] Since Akino and Hayami calculate leftward rather than rightward shifts of the supply curve, their denominator is the yield of the improved variety rather than the "unimproved" variety, as here. The result is a larger k-factor in most cases.

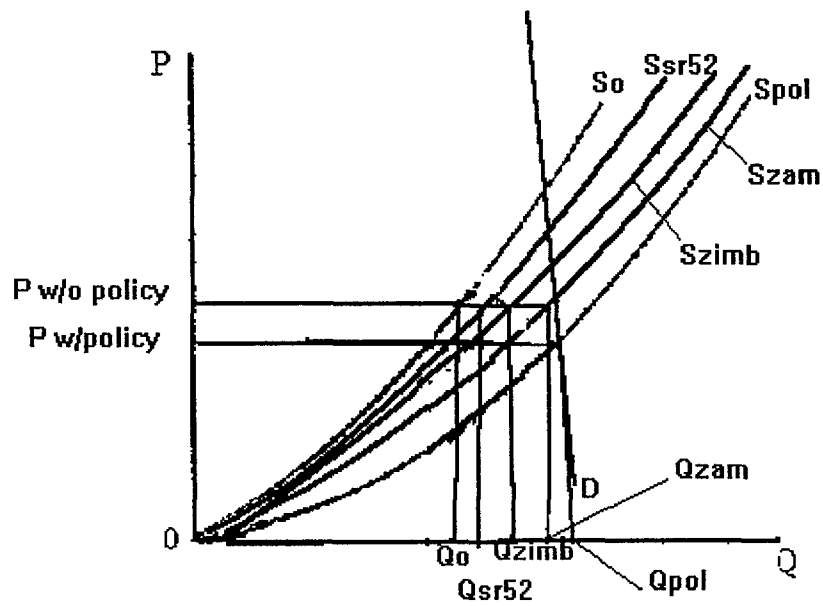

Figure 6: Estimated supply shifts from investments in maize research and policy

SR52 area.

3.4. Estimation of S_{Zam}

$S_{Zam}=(1+h_{Zam})(1+h_{Zimb})(1+h_{SR52})a_I P^e$
where h_{Zam}=the rate of shift in the supply function due to adoption of improved Zambian hybrids;
$h_{Zam} \approx (1+e)k_{Zam}$;
and k_{Zam} = the proportion of maize area planted to Zambian hybrids * (yield increase of Zambian hybrids over local varieties) / yield of local varieties

S_{Zam} reflects the increased production resulting from the availability of improved Zambian hybrids to small/medium and large farmers. h_{Zam} represents the rate of shift in the supply function due to the adoption of Zambian hybrids. It is assumed that small/medium farmers planting Zambian hybrids do not use fertilizer, but large farmers apply the full recommended levels. h_{Zam} is approximated by $(1+e)k_{Zam}$; k_{Zam} is estimated by calculating the yield increase of Zambian hybrids over local varieties, weighted by the average small/medium and large farmer area under Zambian hybrids. Large farmer area was estimated from responses to the MSU/MAFF/RDSB mail-in survey of large farmers. Small/medium area under Zambian hybrids was estimated from MSU/MAFF/RDSB Maize Adoption Survey data.

3.5. S_{Pol}

$S_{Pol} = (1+h_{pol})(1+h_{fert})(1+h'_{Zam})(1+h'_{Zimb})a_I P'^e$
where S_{Pol} = actual maize production in 1987/88 (with technology, policies);
h_{pol}=the rate of shift in the supply function due to fertilizer subsidies, credit programs and locally available input and product marketing services;
$h_{Pol} \approx (1+e)k_{Pol}$;
and k_{Pol} is the residual in the S_{Pol} equation;

h_{fert}= the rate of shift in the supply function due to the yield increase in local varieties resulting from the availability of fertilizers to small/medium farmers;
$h_{fert} \approx (1+e)k_{fert}$;
and k_{fert}= the proportion of maize area allocated to fertilized local varieties * (yield increase of local fertilized varieties over local (unfertilized) varieties) / yield of local (unfertilized) varieties;

h'_{Zam}= the rate of shift in the supply function due to the yield increase in Zambian improved varieties resulting from the availability of fertilizer to small/medium farmers;
$h'_{Zam} \approx (1+e)k'_{Zam}$;
and k'_{Zam}= the proportion of maize area planted to fertilized Zambian hybrids * (yield increase of fertilized Zambian hybrids over fertilized local varieties) / yield of fertilized local varieties;

h'_{Zimb}=the rate of shift in the supply function due to the yield increase in Zimbabwean varieties resulting from the availability of fertilizer to small/medium farmers;
$h'_{Zimb} \approx (1+e)k'_{Zimb}$;
and k'_{Zimb}= the proportion of maize area planted to fertilized Zimbabwean hybrids * *(yield increase of fertilized Zimbabwean hybrids over fertilized local varieties) / yield of fertilized local varieties;

and P' = the actual panterritorial, panseasonal producer price for maize in 1987-88.

S_{Pol} is the actual, known maize production in the "with-policy" situation, 1987-88. The difference between S_{Zam} and S_{Pol} represents the change in maize production resulting from (1) the availability of fertilizer to small/medium farmers for use on local, Zimbabwean hybrids and improved Zambian varieties because of price subsidies, credit programs and distribution systems that made inputs available through local depots; (2) pan-territorial, pan-seasonal pricing for maize; and (3) the establishment of a countrywide system of local depots where small/medium farmers could sell their maize, and, in some cases, have their maize collected from the farm gate. Thus the shift between S_{Zam} and S_{Pol} incorporates interactive effects between fertilizer and local and hybrid maize varieties, as well as the impact of price policy and availability of marketing depots.

In this "with-policy" case, it is assumed that Zambian and Zimbabwean hybrids replace SR52, which drops out of the analysis. For h_{fert}, secondary estimates of the proportion of local maize area fertilized vary widely, from none, to half, to all (ARPT 1983; ARPT 1987; Jha et al. 1991; ARPT 1988). In this analysis, it is assumed that half of local maize area is fertilized in all analysis areas. All small/medium and large Zimbabwean and Zambian hybrid area is assumed to be fertilized at full recommended levels, based on MSU/MAFF/RDSB survey estimates and secondary reports that indicate high levels of fertilizer application to maize by Zambian farmers (CIMMYT 1990; Jha et al. 1991).

Estimates of h_{fert}, h'_{Zimb}, h'_{Zam} supply function shifts are made for small/medium analysis areas, but not for large farmer areas, since large farmers are assumed to fertilize at recommended levels without fertilizer subsidies or local marketing outlets. h_{Pol} is the residual in all areas, $h_{Pol} = S_{Pol} - (1+h_{fert})(1+h'_{Zam})(1+h'_{Zimb})a_1P'^{e}$.

3.6. Calculation of k factors

There are two steps in estimating the k factors (shifts in the production function) associated with each technology type. First, the increase in yield associated with adoption of SR52,

Table 3: Small/medium farmer maize yields under different fertilization levels

tons/ha

Variety	Local			SR52			MM603/ 604			Zimb. hybrids[1]		
Fert. level	0	medium	full[2]	0	medium	full	0	medium	full	0	medium	full
Reg. I	.7	1.3	1.5	.5	1.5	1.6	1	2.4	2.7	1	2.4	2.7
Reg. II	1.5	2.3	2.6	2.0	2.9	3.2	2.0	3.2	3.5	2.0	3.2	3.5
Reg. III	.7	1.4	1.6-1.7	.8	1.5	1.7	2.0	2.5	2.7	1.8	2.3	2.5

Source: personal communications, Gibson, November 1993; Waddington, February 1994

[1] R201, R215

[2] Full recommended level

average yields are assumed (full fertilization), based on Gibson (personal communication, March 1993) and Ristanovic (1988):

SR52: 5.45 tons/ha
Zimbabwean hybrids: 5.85 tons/ha
Zambian improved hybrids: 6.06 tons/ha

The second step is estimating the proportion of maize area under a given technology, with and without policies. Since the proportion of large farmer maize area planted to hybrids (first non-Zambian, then Zambian) remained relatively constant in the 1970s and 1980s, and these farmers were already using fertilizer, it was assumed that large farmers would plant the same proportion of maize area to improved varieties, with or without policies.

However, total small/medium maize area, and the proportion of small/medium maize area planted to hybrids, grew significantly in the same period, implying that farmer area decisions were affected by the policy environment. There is no clear way to estimate the proportion of area that would have been planted to SR52, Zimbabwean or Zambian hybrids in the absence of policies since actual primary and secondary adoption data are "contaminated" by the policies in force since the 1970s.

Given this constraint, the approach followed was to calculate the average proportion of maize area under a given technology, e.g. SR52, in the year before adoption of Zambian improved varieties, from the pool of MSU/MAFF/RDSB respondents for a given analysis area, e.g. Central Province, Region II, small/medium farmers. Three possible scenarios are analyzed: the case where the area planted to SR52 in the without-policy case is (a) 25 percent of the area planted in the with-policy situation; (2) 50 percent of the area planted with-policy; (3) 75 percent of the area planted with-policy.

3.7. Results of simulation

3.7.1. Estimated changes in production 1987-88, with and without maize technology and policies

If no new technology had been available and no policies had been in effect in 1987-88, the estimated total production of maize would have been 1.55 million tons of maize. With technology and policies, the actual production was 1.83 million tons, an overall increase of 18.4 percent. In that year, an additional 63,900 tons were imported. Without technology and policies, the additional shortfall would have been more than 280,000 tons. The analysis shows that under

certain assumptions, national-level maize production would have been higher if technology were available but no policies had been in place. Table 4 shows that, if small/medium farmers planted 50 percent or more of the maize area they planted to Zambian hybrids in the with-policy case, when there were no policies, national maize production would have been higher than the actual 1987-8 levels.

The main assumption underlying the calculation of production in the absence of new technology and policies was that producers in a given area would continue to produce their local consumption requirements and additional maize for export to other provinces in the same ratio as they did in 1971-2. This is optimistic, given the labor constraint, limits of the available local technology, and the inability of agricultural production in other African countries to keep pace with population growth. Therefore the estimate of an 18.4 percent overall increase after policies and technology is probably quite conservative.

Among the different analysis areas, the greatest production increases, in terms of percent change over the without-policy, without technology scenario, were small/medium farmers in Eastern Province Region II (152.4 percent), Southern Province Region I (126.5 percent), and Northern Province Region III (97.2 percent). This supports the hypothesis that the major impact of technology and policies was to facilitate maize production in more remote areas (Northern, Eastern Provinces) and among farmers in drier areas who, with the introduction of shorter-season maize hybrids, were motivated to produce maize on a much larger scale (Southern Province Region I). Increases in production in other small/medium farmer analysis areas were also substantial: the production increase in Eastern Province Region I was 74.5 percent, in other areas was 65.5 percent, and in Central Province Region II was 58.7 percent. The production increase in Southern Province Region II was relatively small, only 7.9 percent.

Production by large farmers in Central and Southern Provinces declined sharply between the without and with policy/ technology scenarios. Central Province large farmers produced 71.6 percent less than predicted if there had been no new technology or policies. The decline in Southern Province large farmer production was 57.7 percent. In all cases except Southern Province Region II, Northern Province, and "other" areas, the impact of policies on production clearly outweighed the impact of the unfertilized maize variety technologies.

Table 4: Production changes with and without policies and technology, 1987-88

	NPR3, S/M,25%	NPR3, S/M,50%	NPR3, S/M,75%	CPR2, S/M,25%	CPR2, S/M,50%	CPR2, S/M,75%	CP,R2,LG	EPR2, S/M,25%	EPR2, S/M,50%	EPR2, S/M,75%
Prod. change with technology, policies (% change from no policies, no technology)	97.2	97.2	97.2	58.7	58.7	58.7	-71.6	152.4	152.4	152.4
Technology contribution (SR52, Zimb.,Zambian hybrids)%	33.0	68.4	106.1	16.3	33.4	51.2	22.8	6.3	12.8	19.7
Policy contribution	66.98	31.63	-6.11	83.7	66.6	48.8	-122.8	93.7	87.2	80.3
Sum pct	100	100	100	100	100	100	100	100	100	100

	EPR1, S/M,25 %	EPR1, S/M,50 %	EPR1, S/M,75 %	SPR2, S/M,25 %	SPR2, S/M,50 %	SPR2, S/M,75 %	SPR1, S/M,25 %	SPR1, S/M,50 %	SPR1, S/M,75 %	SP,R2, LG	OTHER 25%	OTHER 50%	OTHER 75%
Prod. change with technology, policies (% change from no policies, no technology)	74.5	74.5	74.5	7.9	7.9	7.9	126.5	126.5	126.5	-57.7	65.5	65.5	65.5

Technology contribution (SR52, Zimb., Zambian hybrids)%	1.03	2.05	3.06	151.8	310.9	477.1	2.7	5.3	7.7	28.32	30.8	63.4	97.9
Policy contribution	99.0	98.0	97.0	-51.8	-210.9	-377.1	97.3	94.7	92.3	-128.3	69.2	36.6	2.09
Sum pct	100	100	100	100	100	100	100	100	100	100	100	100	100

At the national level, the projections show that 1987-88 production would have been higher than the actual, with-policy levels if farmers had planted improved varieties on 50% or more of the area planted to improved varieties in the with-policy case. The major reason for this is that actual large farmer production in Central and Southern Provinces declined sharply between 1971 and 1987. Large farmer production would have been much higher in any of the projected no-policy scenarios. In all other small/medium analysis areas, with the exception of Southern Province Region II and Northern Province (75 percent), production was higher in the actual, with-policy case than in any of the without policy cases.

The impact of policies was to encourage maize production in remote provinces (Northern, Eastern) and discourage it to an extent in areas closer to consumption centers (Central, Southern). With policies and improved technology in place, close areas produced 51 percent of actual maize production in 1987/88. Remote areas produced 35 percent, and other provinces produced 14 percent. The projections show that, if improved technology had been available, but no policies were in place, closer provinces would have provided 69-72 percent of total maize production, with 18-20 percent from remote provinces, and 10-11 percent from other areas.

The policy environment also facilitated a shift of production from large to small/medium farmers. According to GRZ (1991), large farmers produced about 20 percent, and small/medium farmers 80 percent of total maize production. Without policies, the results of the analysis show that large farmers would have produced more than a third of the total, while small/medium farmer share would have dropped to 65-70 percent.

3.7.2. Producer and consumer surplus

Changes in producer surplus resulting from the implementation of maize-related programs were calculated using the Akino-Hayami formulas. In the without-policy case, farmers in close areas have the highest share of producer surplus under every assumption, the proportion of remote and other areas' producer surplus increases as area planted to improved varieties rises. When policies and improved technology are in place, producer surplus for close areas is negative, but positive for remote and other areas. Large farmers are in the close category, and their maize area and production drop sharply with the implementation of policies and corresponding fall in prices. Most remote and other farmers continue to expand production with the implementation of policies, resulting in increased surplus.

Comparing producer surplus of large and small farmers, in the without-policy case, large farmers gain half or more of total producer surplus when small/medium farmers are assumed to plant a small proportion of maize area (25 percent of the with-policy area) in improved varieties. Small/medium farmer share of producer surplus rises as area planted to improved maize varieties increases. In the actual, with policy and with technology case, large farmer producer surplus is negative, and small/medium surplus is positive. Large farmer production declines when policies are put into place, while small/medium farmer area and production continue to expand overall.

Urban consumers in Zambia benefitted from government pricing policies that kept urban consumer prices lower than the import parity price. Total urban consumer surplus of more than ZK 839 million compares to total producer surplus of **negative** ZK 61 million in the with-policy, with improved technology case. When the whole package of maize policies, including consumer subsidies[12], are considered, consumers were by far the greatest beneficiaries.

3.7.3. Revised ARR

Information from the preceding analysis was used to estimate a revised ARR to technology investments in the absence of key price and marketing policies. The revised estimates represent the returns to investments in development and dissemination of Zambian improved hybrids when fertilizer is available to large, but not small and medium farmers.

Since in the Zambia case there are no observations of production behavior in the no-policy case, sensitivity analysis is again used. The ARR is calculated under the assumption that farmers plant, alternatively, 25 percent, 50 percent or 75 percent of the small/medium farmer with-policy maize area to SR52, Zimbabwean hybrids and Zambian varieties.

The "without case" assumes that large farmers plant SR52 and Zimbabwean hybrids with the full recommendation of fertilizer. Small/medium farmers plant local maize, and 25 percent (50 percent, 75 percent) of with-policy areas of SR52 and Zimbabwean hybrids, but use no fertilizer. The "with" case assumes that large farmers use fertilized Zambian varieties in addition to SR52 and Zimbabwean varieties. Small/medium farmers plant 25 percent (50 percent, 75 percent) of the with-policy area of Zambian varieties, in addition to locals and 25 percent(50 percent, 75 percent) of SR52 and Zimbabwean hybrids, all unfertilized.

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[12] Consumer subsidies were excluded from the ARR calculations.

Since large farmers use the same level of fertilizer in the without and with cases, and small/medium farmers use no fertilizer in either case, there are no differences in production costs between the with and without cases. Research, extension and seed costs are the same as in the original ARR calculation, but marketing costs are omitted here.

The ARR for the 25 percent case is 65 percent in the 1978-2001 period and 77 percent for 1978-91. The revised ARR in the 50 percent case is 85 percent and 68 percent in the 1978-2001 and 1978-91 periods. In the 75 percent case, the ARRs are 96 percent and 84 percent, respectively. All without-policy ARRs are substantially higher than the with-policy ARR. The with-policy ARR is negative in the 1978-91 period and 49 percent from 1978-2001, while the without-policy ARRs range from 68-96 percent.

4.0. Conclusions

The Zambia case study suggests that the results of rate of return to research studies may be overstated if they calculate an ARR counting the benefits of technology adoption but only the costs of research, if technology transfer to targeted groups depends on simultaneous investments in complementary institutions and policies. Crediting research investments alone with a high ARR can send dangerously misleading policy signals, if this masks additional investments needed to facilitate adoption of technology by target farmers that in turn affect economic feasibility.

Second, the effect of policies on the ARR, adoption pattern and distribution of benefits from technology can be dramatic. In the Zambia case, the ARR in the absence of marketing policies might have been slightly higher, but then the beneficiaries of maize technology would have been primarily large and medium-scale farmers and small farmers in areas close to the line-of-rail and urban consumption centers. In the actual, with-policy case, large farmers lost market share while small farmers in remote areas entered the commercial maize market.

Third, the benefits of technology development and its adoption by targeted groups extend beyond increased national income. In Zambia, policies aimed to draw more remote small farmers, up to independence largely excluded from development, into the commercial agriculture market. Their incomes increased, and they learned how to grow new varieties and use fertilizer. Perhaps social stability was enhanced by this, and by the provision of cheap mealie meal to urban workers.

Fourth, although recognizing the importance of political and social motives behind Zambia's package of maize policies, in the end it was unsustainable. The policies promoted a pattern of maize production that was uneconomic. Transportation and handling costs from remote

areas to urban centers were too high to allow continued support for major production of maize by far-off farmers. Also, the institutional and organizational environment inhibited the evolution of innovations that would have reduced these costs, or facilitated the movement of newly commercialized farmers to more valuable crops than maize.

The current emphasis on liberalizing agricultural marketing in Zambia addresses the first problem, uneconomic maize production patterns. The removal of subsidies has already drawn some maize production away from the more remote areas and back to the line-of-rail provinces. However, the institutional/organizational foundation for evolving stronger, more diversified markets remains weak. Because of this there is a risk of setting aside the developmental gains achieved (if expensively) during the 1970s and 1980s. The decline of maize production in areas where it is uneconomic to produce and transport it to Zambia's major urban areas is not to be mourned, but the lack of aggressive policies and programs, which would encourage a mixed public-private sector to build on gains of the last two decades to develop new technology and explore commercial production of more economic crops and livestock, is.

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