# *Staff Paper*

**Getting Technology and the Technology Environment Right: Lessons from Maize Development in Southern Africa**

**by**

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Abstract

This paper examines two questions: (1) what were the most important factors that led to differential rates of adoption of maize technology by farmers in Zimbabwe, Zambia, and Malawi from 1910 to 1995? and (2) what do these experiences suggest about strategic investments in institutions and organizations needed to create a sustainable environment for technology development and adoption in the future? The analysis suggests that productivity increases are facilitated by (a) technology innovations throughout the agricultural system, (b) integration of technological innovations with changes in policies, organizations, human capital and infrastructure related to extension, input and output markets and processing services, and (c) coordination of these innovations across different stages of the agricultural system.

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# Getting Technology and the Technology Environment Right: Lessons from Maize Development in Southern Africa

## Introduction

In contrast to the gloomy scenario usually painted for African agriculture, this paper examines the experiences of three countries in southern Africa (Zimbabwe, Zambia, and Malawi) where there has been considerable success over the last 90 years with the development and spread of improved maize, the region's most important food crop. There have been three major breakthroughs in maize technology: (1) the replacement of traditional flinty[1] open-pollinated varieties (OPVs) with higher-yielding white dent OPVs beginning in the 1920s; (2) the spread of the Zimbabwean hybrid SR52 throughout the region during the 1960s; and (3) the development of shorter-season hybrids adapted to smallholder conditions.

The pace and extent of improved maize technology adoption differed among the countries. SR52 was rapidly adopted by large-scale commercial farmers[2] in Zimbabwe and Zambia: Zimbabwean maize production jumped by 114 % between 1960-64 and 1970-74, and yields doubled in Zambia. Adoption of hybrids in Malawi was much slower because of its relatively small commercial maize sector. After shorter-season hybrids became available, smallholder adoption of hybrid maize jumped from 50 to 100 % (of maize area) in Zimbabwe, and from 30 to 60 % in Zambia and 3 to 18 % in Malawi between 1965 and 1992. Maize production more than tripled in

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[1] The texture of maize grain ranges from hard (flint) to soft (dent).

[2] In this paper, "commercial farm" refers to a very small group of large-scale, highly mechanized farms of up to 2,200 hectares, predominantly owned and operated by white settler farmers of European origin. The majority of smallholders in the three countries are primarily subsistence or semi-subsistence farmers cultivating from one-half to three hectares per household. Medium-scale African commercial farmers make up a third (small) group, cultivating from 5 to 40 hectares.

Zambia and doubled in Zimbabwe over the last 30 years (Eicher, 1995; Howard, 1994; Heisey and Smale, 1995).

The availability of new maize seed and fertilizer technology was essential, but by itself not sufficient to make increases in large commercial farmer and smallholder productivity possible. Maize productivity increased because of improvements made in the entire agricultural system,[3] including (1) **technology** innovations throughout the system, not just on-farm; (2) integration of technological innovations with changes in the **technology environment**, i.e., policies, organizations, human capital and infrastructure related to extension, input and output markets, processing services, and consumption, and (3) **coordination** of these innovations across different stages of the agricultural system (Bonnen, 1990; Maredia et al., 1997; Boughton et al., 1995). Maintaining the enabling environment involved heavy financial subsidies from the government that ultimately became unsustainable. Beginning in the early 1990s, the liberalization of maize and input marketing increased uncertainty about maize prices and decreased the availability of seed, fertilizer, and credit. These factors led farmers to "disadopt" fertilizer and seed technology in the mid-1990s.

This paper examines maize technology, the technology environment and coordination in the region to answer two questions: (1) what were the most important factors that led to differential rates of adoption of maize technology by large farmers and smallholders in Zimbabwe, Zambia, and Malawi from 1910 to 1995? and (2) what do these experiences suggest about

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[3] The agricultural system involves many different stages, including agricultural inputs, farm-level production, processing, storage, assembly, transportation, marketing and consumption. Agricultural research and extension can potentially contribute improved technology at any of these stages.

strategic investments in institutions and organizations needed to create a sustainable environment for technology development and adoption in the future?

**Socioeconomic and Agroecological Characteristics**

Maize was originally introduced to southern Africa by Portuguese traders in the 16th century. These maize varieties were flinty, low-yielding, and varied in color. Small farmers traditionally grew maize as one of a mixture of crops that also included sorghum, millet, pumpkins and groundnuts, but maize did not become dominant in most systems until the arrival of European colonizers in the 1900s (Blackie, 1988). The major maize growing environments in all three countries are mid-altitude (900-1,800 meters above sea level), with rainfall ranging from 650 mm to over 1000 mm annually.

Colonial governments and companies encouraged European settlement and development of farmland in all three countries during the early 1900s, establishing dualistic agricultural sectors that persisted beyond independence.[4] European farmers in Zimbabwe and Zambia controlled much of the better agricultural land, producing maize for export, and to feed mine and industrial workers in urban areas. By contrast, European settlement and industrial development in Malawi was relatively limited, and large estates there concentrated on tobacco and tea, not food production (Heisey and Smale, 1995).

**Technological Change**

*From traditional flinty OPVs to higher-yielding white dent OPVs*

Between 1910 and 1913, research stations were established in all three countries to test imported maize varieties from the U.S. and South Africa such as Hickory King and Southern

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[4] Zambia and Malawi became independent in 1964, Zimbabwe in 1980.

Cross. These new varieties differed from the traditional varieties in color (white, rather than variable color) and grain quality (dent, rather than flint). By the 1920s, these higher-yielding white dent cultivars had begun to replace the traditional varieties among both commercial farmers and smallholders in Zimbabwe and Zambia (Weinmann, 1972). The acceptance of dents by farmers and consumers was an important watershed because the pool of available germplasm from South Africa, the U.S., and Europe was dominated by populations with dentier rather than flintier grain quality. This meant that in the future it would be easier and faster for Zimbabwean and Zambian scientists to achieve improved open-pollinated varieties and hybrids, because they could draw upon the large worldwide base of dent populations. The research program in Malawi placed more emphasis on improving the traditional flint varieties used by smallholders. Although many maize varieties grown in South America are flinty, it was not until the 1980s that this germplasm became accessible to African scientists and was adapted to African mid-altitude conditions.

*The development and spread of white dent hybrids*

Technological change in the region through the mid-1960s was led by Zimbabwe, where there was early and continuous support for agricultural research from the colonial government and European settler farmer associations. Stable funding for research and the creation of attractive working conditions for researchers were critical factors in subsequent maize breeding breakthroughs. There was remarkable continuity in the maize program: only four senior breeders guided Zimbabwe's maize research from 1932 until 1988. H.C. Arnold released the first hybrid, ZH1, in 1949; the spectacularly successful SR52, a long-season, denty hybrid, followed in 1960 (Eicher, 1995).

After the formation of the Federation of Rhodesia and Nyasaland in 1954, many agricultural research activities were transferred from Zambia and Malawi to Zimbabwe. Improved access to Zimbabwe's superior research facilities and improved varieties, especially the new dent hybrids, clearly benefitted Zambian and Malawian farmers, but stunted the development of Zambia's own research programs. Malawi was less affected; local research continued to be important because of the unique emphasis on developing flint varieties for smallholders.

SR52 had immediate and powerful impacts on Zimbabwe and Zambia's commercial farm sectors. By the late 1950s, over 80% of Zimbabwe's commercial farm area was planted to hybrids, and Zambian large farmer yields doubled (Makings, 1966). Malawi was hardly touched by the hybrid breakthroughs; in 1980 less than 5% of total maize area was planted to hybrids (Rusike, 1995).

*Development of smallholder-appropriate hybrids*

A serious problem facing smallholders interested in planting SR52 was the long growing period that required early planting. SR52 was especially risky for farmers in drier, drought-prone regions. Only 20% of smallholders in Zimbabwe were using hybrids by 1965, and only 30% of smallholder area in Zambia was ever planted to SR52 or its advanced generations (Kupfuma, 1994; Howard, 1994).

In Zimbabwe, the impetus for developing shorter-season hybrids came again from large-scale farmers. The imposition of UN sanctions against Zimbabwe following the Unilateral Declaration of Independence (UDI) from Great Britain in 1965 halted the most important agricultural export, tobacco, and commercial farmers in drier areas sought to diversify away from tobacco to maize, cotton, wheat, soybeans, and coffee (Eicher, 1995). In the late 1960s, Zimbabwean scientists developed 3-way short-season hybrids that fared better in lower or unreliable rainfall areas. These qualities made R200, R201, and R215 suitable for smallholders as well as commercial farmers in Zimbabwe and elsewhere. By 1976, an estimated 50% of smallholder area in Zimbabwe was planted to hybrids, and R series hybrids were exported throughout the region (Rusike,1995).

Zambia and Malawi's progress toward hybrid development was slower, partly because after independence the maize programs depended on donor-funded expatriate breeders who had short tenures, brought conflicting views of maize breeding priorities, and left breeder-less periods between advisers when critical lines became contaminated (Howard, 1994; Rusike, 1995). Smallholders were also poorly organized and lacked the clout to set research priorities as the Zimbabwean commercial farmers had. Research priorities were instead decided by government officials and donors.

In the late 1970s, donors and international organizations stepped up their support for sustained, focused maize programs in both countries. Key concerns were (1) the choice of open-pollinated vs. hybrid varieties for smallholders, given their uncertain access to seed and fertilizer; and (2) the importance of flint vs. dent grain quality for smallholders.

In Zambia, ten dent hybrids and two flinty open-pollinated varieties were released between 1984 and 1995. The characteristics of the new hybrids addressed several issues in the open-pollinated vs. hybrid debate: (1) the new varieties were disease-resistant and up to 7 weeks earlier than SR52; (2) in all but the most adverse environments, hybrid maize outyielded local (and improved) open-pollinated varieties, even without fertilizer; (3) several new hybrids were double or three-way crosses, thus their yields were more stable than the single-cross SR52 if farmers planted second generation seed; and (4) the yield in seed production from three-way crosses was as much as three times higher than from single crosses, reducing the unit cost of maize seed production. The new hybrids were extremely popular among smallholders. Their potential yields were 5-8 tons, compared to 1-2 tons for local varieties (Howard, 1994).

Malawi's hybrid program was revived in 1977 after a ten year hiatus, and several dent hybrids and semi-flint composites were released beginning in the late 1970s. The improved varieties were not immediately adopted by smallholders; less than 7% of maize area was planted to hybrids by the late 1980s (Rusike, 1995). Kydd attributed the adoption problems to an early misdiagnosis of the importance of the smallholder processing and dietary preference for flinty maize, and the subsequent failure to make truly flint improved varieties available (1989). Following increased pressure from the World Bank, the flint hybrid breeding program was initiated in 1987. By 1990, two semi-flint hybrids were released that outyielded local varieties without fertilizer under conditions of relatively good natural soil fertility (Heisey and Smale, 1995; Rusike, 1995).

**The Technology Environment and Coordination**

Four key factors figured in the creation and coordination of a technology environment that encouraged adoption of maize hybrids by farmers through the early 1990s: (1) commercial demand for maize and the resulting political pressure for improving the policy and organizational environment; (2) subsequent changes in marketing and price policies; (3) development of the seed industry; and (4) increased access to seed, fertilizer, and credit for smallholders.

*Influence of commercial demand and political interest on the technology environment*

The growing demand for maize in urban centers of Zimbabwe and Zambia and for export was the primary catalyst for the replacement of traditional flinty OPVs with imported higher-yielding denty OPVs and later hybrids. With rapid mining and industrial development, maize became an important wage good for urban workers. The large commercial demand for maize lent political muscle to farmer groups and industrialists attempting to promote and control the maize production, marketing, and processing system. After independence, the new majority governments sought to improve equity and gain popular support by implementing maize programs with highly visible benefits.

Malawi remained largely rural, and perceived its development challenge differently. It had neither significant commercial demand for maize as an export or wage good, nor the settler-farmer and industrial organizations to lobby for favorable changes to the policy and organizational environment. The engine of Malawian economic growth was rural-based smallholder and estate export agriculture (Jones, 1994).

*Marketing and price policies*

Maize price controls and subsidies to maintain market infrastructure began with the colonial governments during the 1930s. In Zimbabwe, Zambia, and initially Malawi the colonial governments wanted to export[5] and supply maize to urban centers while protecting the large white commercial farmers' share of the maize market. After independence, the majority governments continued to control and subsidize maize marketing; they still wanted to deliver

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[5] The rapid changeover from flint to higher-yielding white dent varieties was partially motivated by the growing demand for white maize by the English starch industry. After the outbreak of World War I arrested exports, Malawi lost interest in white dent production.

maize to the cities but also sought to integrate rural smallholders into the commercial maize market. To do so governments subsidized the establishment of marketing services to smallholders throughout the country and implemented panterritorial, panseasonal pricing policies. The policies kept maize prices far below border equivalent levels, discouraging production in areas close to major consumption centers, and accelerating it in remote areas where farmers had few if any commercial crop alternatives. As production shifted to more remote areas the costs of providing marketing services rose dramatically. Well over half of maize in Zimbabwe and Zambia was marketed through official channels until the early 1990s. Maize bought by official marketing organizations was resold to parastatal milling companies in urban areas, where it was processed into maize flour and other products, which were then sold at controlled prices to urban consumers.

The policies affecting maize marketing, storage and processing also reinforced the dominance of denty maize hybrids in Zimbabwe and Zambia. Denty maize grain is favored by modern mills because the softer grains cause less wear-and-tear on machinery. In Malawi most maize flour was still produced in rural areas, by hand. Flinty varieties were preferred for their higher flour-to-grain extraction rate (Heisey and Smale, 1995). Because panseasonal pricing meant there were no returns to on-farm storage of commercial maize in Zimbabwe and Zambia, the greater vulnerability of denty hybrids to pests in traditional storage bins was not an issue, but it was of tremendous importance in Malawi, where most maize was stored on the farm.

Malawi's marketing board, the Agricultural Marketing and Development Corporation (ADMARC) also subsidized maize producers and consumers, distributed subsidized fertilizer, and used panterritorial pricing to subsidize the cost of transport from the maize surplus, less populated

North to the maize deficit South, but these activities were never as extensive as those to promote export agriculture. ADMARC controlled only an estimated 20% of maize production. In contrast to Zimbabwe and Zambia, few of the benefits of ADMARC investments reached smallholders. Instead ADMARC used its statutory export monopoly over smallholder agricultural production to generate revenue for lending to the estate sector (Jones, 1994).

*Development of the seed industry*

The nucleus of the seed industry in Zimbabwe and Zambia was a group of large commercial farmers who possessed the management skills needed to produce technically demanding hybrid seed. The need to ensure that quality seed was available in order to produce a uniform export product led Zimbabwean growers to form the Seed Maize Association in 1940, pressure the government to set and enforce standards for certified seed, and negotiate an agreement that permitted the Seed Maize Association to produce and market all hybrid seed released by the Harare Research Station. Hybrid seed was widely available through the Seed Co-op's marketing network of private distributors, wholesalers and retailers (Eicher, 1995; Rusike, 1995).

Zambian seed maize producers formed an association in 1963, but were denied permission to launch a private seed marketing company by the new majority government. Instead, the Swedish International Development Authority (SIDA) helped establish a parastatal seed company, Zamseed, in the early 1980s. To ensure the new company’s viability, Zamseed encouraged maize researchers (also SIDA-funded) to develop hybrids that would have to be purchased every year instead of OPVs that could be saved on the farm and replanted (pers. comm., B. Landless).

In the 1950s, there were no seed growers in Malawi who could multiply improved varieties produced by the research stations, and no seed laws promoted or protected the development of a seed industry (Rusike, 1995). ADMARC and the Ministry of Agriculture were responsible for seed production until a parastatal seed company was established in the late 1970s. The ability of ADMARC and the parastatal to produce and distribute seed fluctuated erratically with their fiscal solvency (Heisey and Smale, 1995).

*Improving smallholder access to credit and fertilizer*

The expansion of the cooperative depot system in Zimbabwe and Zambia also made it possible for smallholders throughout the country to obtain subsidized credit and inputs locally through government programs. As a result, smallholder fertilizer consumption more than quadrupled in Zambia and Zimbabwe between the 1960s and the late 1980s (Rusike, Reardon, Howard, and Kelly 1997).

Hybrid seed use rose, and fertilizer consumption by smallholders in Malawi tripled during the late 1980s, after credit programs were significantly expanded and the seed system stabilized. From 1984-85 and 1987-88, hybrid maize accounted for less than 15 % of maize production, but the proportion quickly climbed to one-quarter in 1989-90, one-third in 1990-91 and over one-half by 1994-95 (HIID/GOM, 1994). Smallholders were adopting dents prior to the early 1990s because those were the only improved varieties available during that time. This suggests that the smallholder preference for flint maize may not be as fixed as Kydd and others have assumed, but that other factors such as seed and credit availability were critical constraints to adoption of hybrids in Malawi.

**The Process of Structural Reform**

By the mid-1980s, government subsidies to the maize sector became financially unsustainable, consuming 17% of the total Zambian government budget by 1988 (GRZ, 1990). In Zambia and Zimbabwe, skyrocketing marketing board costs were the primary factor, as the scale and complexity of their activities increased. The resulting problems snowballed through the system. Marketing agencies paid producers late, resulting in farmers' subsequent inability to pay loans on time. Liquidity problems for the credit and input agencies led to late procurement and delivery of inputs in the following season (Howard, 1994). In Malawi, credit recovery rates declined through the late 1980s, until very low repayment in 1993 led to the state credit agency's collapse in that year (Heisey and Smale, 1995). The financial crisis also significantly weakened government support for research and extension. The Zimbabwean maize research budget fell by more than 25% between 1980 and 1990, and by more than 70% in Zambia between 1985-90 (Eicher, 1995; Howard, 1994).

The World Bank, IMF and donor agencies subsequently began to promote the reform of food marketing agencies in Zimbabwe and Zambia, conditioning future loans on the removal of regulatory restrictions on the private sector and the withdrawal of the state from direct marketing functions. In Zimbabwe, the reforms have opened the market to private sector participation, but the marketing board and panterritorial floor prices have been retained. Deficits have continued to accumulate because although the marketing board has a mandate to serve remote areas, floor prices are too high to allow it to recoup its transport and handling costs.

In Zambia, consumer maize meal subsidies represented a "social contract" between President Kaunda's UNIP government and Zambian urban residents. Initial attempts at reforms and the resulting meal price increases sparked urban riots in 1986 and 1990. The election of President Chiluba in 1991 eventually made possible the implementation of much more dramatic reforms than Zimbabwe's. By 1995 the central marketing agency had been abolished and maize marketing had been completely privatized.

Reforms implemented in the late 1980s and early 1990s also ended price subsidies and parastatal domination of fertilizer and seed production, importation and distribution in all three countries. The entry of private companies greatly expanded the number of fertilizer and seed products available. For example, the number of maize hybrids and open-pollinated varieties available to Zambian farmers doubled between 1992 and 1996. The private seed companies have a strong international research base, and many of the hybrid breeding responsibilities that had been carried out by the national maize research and extension teams are being effectively devolved to the private sector (Rusike, Howard, and Maredia 1997).

**Supply Response to Structural Reforms**

By the mid-1990s, structural reforms in the agricultural sector had elicited three distinct responses. First, the liberalization of maize processing brought a very good response from private hammer millers in Zimbabwe and Zambia. After subsidies on industrially milled meal were eliminated in the early 1990s, large-scale millers lost a major part of their market share to urban hammer mills. The cost of whole meal averages about 60 to 75 % of the retail price of roller meal, and the share of hammer-milled meal in total consumption rose to 40 to 55 % in Zimbabwe and Zambia after liberalization. This suggests that one very positive result of the reforms has been an increase in urban food security through the provision of a lower-cost alternative to industrial meal (Jayne et al., 1997).

Second, producers in areas served by established transportation and trading networks have largely benefitted from the reforms. The liberalization of foreign exchange markets removed the bias against agricultural exports (produced mainly by large-scale farmers and agribusinesses). Exports more than doubled in value between 1992 and 1996 in Zambia and became more diversified. A variety of private contracting arrangements also emerged in Zambia and Zimbabwe to facilitate input provision, commodity production, and trade, in areas with good transport and trade infrastructure (Howard and Mungoma, 1997).

But, third, there has been a dramatic reduction in maize area and use of improved inputs by smallholders, and a reversion to subsistence crops such as sorghum, millet, groundnuts and mixed beans, especially in the more remote and drier regions. By 1995 total cultivated area in Zambia had declined by more than 15% from the 1985-90 average, mainly due to the reduction of maize area. Input use also declined in all three countries due to the contraction of credit. Fertilizer use in Zambia dropped by 70% between 1987-88 and 1995-96 and hybrid maize seed sales declined from 15,000 tons in 1989-90 to 2,500 tons in 1994-95. Smallholder fertilizer use in Zimbabwe fell from 127,000 tons in 1984-85 to 29,000 tons in 1995-1996. In Malawi, fertilizer sales to smallholders for use on maize in 1993-94 were less than half of the previous year's record high, 70,000 tons compared to 144,000 tons, and hybrid maize seed sales fell by nearly 60% in the same year (GRZ, 1995; Rusike, Howard, and Maredia 1997; Rusike, Reardon, Howard and Kelly 1997; HIID/GOM, 1994).

**Conclusions and Policy Implications**

The World Bank's Task Force on Poverty in sub-Saharan Africa has concluded that economic growth is not sufficient to reduce poverty unless the pattern of growth leads to increased production and employment opportunities for the poor (1996). The southern Africa experience with maize development during the 20th century demonstrates that technology can dramatically increase agricultural production and growth in Africa, and that the technology environment and coordination critically influence the pattern of agricultural growth by (1) determining the agenda for technology development; and (2) establishing who will benefit from technology spread.

Initial results from the implementation of structural reforms in the region suggest that countries are regressing to a bimodal pattern of agricultural development, with commercial farming along the main transport and trading arteries and in established estate areas, and subsistence farming in more remote regions. A key question now is how improvements in technology, technology environment and coordination can contribute to **broad-based** economic growth, toward the creation of an economic pie that is not only growing, but is shared by a large part of the population. Key areas for improvement include: (1) strengthening smallholder organizations; (2) strategic public sector investments to reduce the cost of agricultural intensification; and (3) linking high-value commercial crops to the dissemination of foodgrain technology in areas where maize and other bulky foodgrains are not commercially viable.

*Strengthening smallholder organizations*

The experience of large-scale farmers in both the colonial and post-independence periods underscores the importance of having a seat at the policymaking "table." Large-scale farmer organizations set and financed research system priorities, exerting pressure on the research system to develop dent OPV and hybrid technology. They also influenced the formulation of policies to protect their markets, set prices at acceptable levels, and made private investments in seed production and distribution. The relationship between smallholders, research systems, policymakers, and private investment has been much more indirect, because of the absence of smallholder organizations that could effectively articulate the needs of smallholder clients, organize user financing of research, or stimulate complementary private investments.

Stronger smallholder associations in remote areas can also play an important coordinating role in input and product marketing, e.g., aggregating seed and fertilizer orders to reduce transportation costs, and negotiating joint marketing or forward contracting arrangements with distant buyers. In addition, they can educate their members to use credit responsibly and facilitate group-lending programs with penalties for non-repayment enforced by the association.

*Strategic public sector investments to reduce the cost of intensification*

Although the private sector is playing an increasingly important role in input and output marketing, strategic public expenditures are vital to facilitate continued private sector investment and provide services in areas where the private sector has less interest. There are two critical areas for public investment: (1) strengthening research, extension, and smallholder seed access; and (2) reducing the costs of exchange.

Public investments in research and extension over the last 85 years played a key role in increasing yields and reducing the costs of maize production. Today maize research and extension are rapidly evolving toward the system common in developed economies, with breeding and extension activities shared by the public and private sectors. It is already apparent that private seed and fertilizer companies will concentrate on areas where they can realize a profit (e.g., hybrid maize and export crops), and they will confine distribution to areas close to major transportation arteries. This leaves to the public sector a wide swath of important research, extension and seed areas that are critical for increasing smallholder food grain productivity, e.g., breeding, smallholder seed production and distribution, agronomy, and soil fertility for OPV and foodgrain systems.

Railway lines and road networks financed by the state and private companies in colonial days reduced exchange costs for large-scale commercial and estate farmers. New investments could significantly lower transport costs in smallholder areas, making inputs cheaper, farmgate prices more attractive, and stimulating increased private investment.

Private sector financing and delivery of inputs for maize and other commodities is seriously threatened by another type of exchange cost, contract enforcement. To encourage further private sector investment in the agricultural sector, both businesses and farmers need a working and accessible judicial system to enforce contracts, e.g., for repayment of input credit on the businessman's side, and to assure delivery of quality inputs and payment for commodities, on the farmer's.

*Encouraging linkages between commercial and foodgrain channels*

Southern Africa's experience with hybrid maize demonstrates the power of commercial demand as a catalyst for new technology development and spread among both large-scale farmers and smallholders. In areas where maize and other bulky foodgrains are not commercially viable on their own, production of higher-value export crops, or joint export/foodgrain production, may be economic. Governments and donors could provide incentives to the private sector to better integrate commercial and foodgrain production in these areas. For example, cotton companies in Mali and Mozambique have twinned export crops with foodgrains to meet the food requirements of smallholder producers and sell the surplus in urban areas. The companies facilitated the adoption of foodgrain technology by extending the production, input and product marketing services already established for cotton to foodgrains. Transportation, storage and handling costs are shared between the two enterprises. The risks of providing credit for foodgrain inputs in such systems are diminished because farmers are tied to the single-channel market for the export crop, cotton.

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