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The Distribution of Benefits from Bt Cotton Adoption in South Africa

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Technology adoption can create income benefits for large and small-scale producers, input suppliers and consumers in developing countries. The circumstances under which this income creation can take place are shown to depend on a wide range of factors applicable across dualistic agricultural practices in South Africa. Whether for large commercial farms or small-scale agriculture, four factors influence the creation of surplus. World prices, subsidies in developed countries, domestic market structure, and the presence of substitute import markets each play a role in the distribution of rents from Bt cotton, an appropriate technology for South African farmers.

Key words: genetically modified, peasant farmers, welfare benefits

Introduction

Previous work by Ismaël, Beyers, Piesse, and Thirtle (2001) focused on the initial performance of Bt cotton among small-scale farmers in South Africa (SA), and a study by Gouse and Kirsten (2002) compared small-scale and large-scale farmers' reasons for adopting Bt cotton by examining farm-level effects of adoption. Recent research by Beyers, Ismaël, Piesse, and Thirtle (2002), Ismaël, Bennett, and Morse (2002a, 2002b), Gouse, Kirsten, and Jenkins (2003), and Shankar and Thirtle (2003) has continued to examine genetically modified (GM) crops in South Africa, but little has been done to consider the impacts of GM crop adoption on the welfare of farmers and consumers in the country. Purcell and Perlak (2004) and others have presented a glowing picture of Bt cotton for small farmers without considering factors (in addition to the technology itself) that may influence who will benefit from its adoption.

Multinational agricultural biotechnology and seed companies have devoted significant resources to developing and commercializing new genes, varieties, and products tailored to South African growing conditions. We expect that part of the monetary benefit from the adoption of GM crop technologies in South Africa will go to these companies, but how much of the welfare gains do they actually harvest? Many factors influence farmer adoption, including technical considerations, risk aversion, profitability, social acceptability, and environmental considerations; there is a substantial literature on factors influencing adoption of agricultural input biotechnologies in both developed and developing countries. Farmers' benefits might also depend on other resources at their disposal, their social condition, and household priorities. We focus our analysis on three groups of farmers who have adopted Bt cotton, and we consider the distribution of benefits between them and others in their supply chain.

The distribution of economic rents from an agricultural input biotechnology innovation has been examined previously for developed country agriculture. Moschini and Lapan (1997) stressed the importance of intellectual property rights (IPR) in determining how much of the benefit accrues to input or technology suppliers. Falck-Zepeda, Traxler, and Nelson (2000) find that with strong IPR protection in the United States, 59% of the benefits from the adoption of Bt cotton still goes to US farmers, with only 21% going to the developer and intellectual property holder—the input supplier Monsanto. US consumers get 9%, rest-of-world consumers 6%, and the supplier of germplasm gets 5%. Pray, Ma, Huang, and Qiao (2001) extend these results to a developing country by showing that with weak IPR protection, Chinese farmers "obtained the major share of benefits" and small farmers in particular benefited greatly. Calling their estimates conservative, Pray et al. (2001) calculated the Chinese farmers' benefit share at 82.5–87%, whereas the additional benefit accruing to Monsanto and Delta and Pineland amounted to only 6%.

South Africa is marked by a strong system of IPRs and a dualistic agricultural system with large- and small-scale farmers operating under similar (but not identical) market access conditions. Genetic modification technologies have been characterised by an impressive adoption rate among both groups. According to Gouse et al. (2003), large-scale cotton farmers reported pesticide and application cost savings and peace of mind about bollworms as the major benefits of Bt cotton, whereas small-scale farmers indicated saving on pesticides and yield increases as the major benefits and reasons for adoption. We start by considering if farmers experienced increased yields and different input costs, and how these compared to the higher cost of the technology, to set the stage for consideration of market structure at various points in the supply chain in South Africa.

Data and Methods

This paper makes use of data collected on large-scale cotton farmers by the University of Pretoria (UP) and small-scale cotton farmer data that was gathered by UP in collaboration with the University of Reading in the United Kingdom. Data on small-scale farmers was gathered through a survey on the Makhatini Flats in northern KwaZulu Natal in 2000. Data was collected mainly for the 1999/2000 cotton production season. A total of 100 adopting and nonadopting farmers were surveyed; the collected production data was, as far as possible, verified and augmented with data maintained by the Vunisa Cotton Ginnery, Makhatini's credit supplier and seed-cotton buyer.

In order to obtain production and opinion information from large-scale cotton farmers, farmers were visited on their farms during the 2000/01 production season, and a comprehensive questionnaire was completed for each farmer. Both irrigation and dryland farmers were surveyed. Very few of these large-scale cotton farmers planted only one cotton variety. Large-scale farmers were thus more easily able to compare the performance of new modified seeds with that of conventional varieties. A total of 43 large-scale cotton farmers were surveyed in the Northern Province, Northern Cape, and Mpumalanga Province in South Africa. Even though the sample is small, farms were selected to be as representative as possible, covering a range of growing conditions. Data on seed prices and the levied technology fees were obtained directly from Delta and Pineland and Monsanto.

In this paper we rely on earlier work by Huang and Sexton (1996), Alston, Norton, and Pardey (1995), and Alston, Sexton, and Zhang (1997), who showed that imperfectly competitive markets influence the size and distribution of benefits from research. We document how the biotechnology and plant germplasm suppliers act as monopolists. We show how the consumers of farm output—the seed-cotton gins in the case of cotton—are effectively purchasing farmer's output under competitive conditions. Depressed world cotton prices, which are in turn partly influenced by subsidies periodically enjoyed by farmers in developed and other large cotton-producing countries, also play an important role. Finally, the presence of seed cotton from international markets can substitute for domestic production and further reduce the market power of both large- and small-scale producers. The technology treadmill that has been shown to be a mixed blessing in developed countries (because increased production lowers prices) seems to only operate in developing countries under the most favorable conditions; possibly the only thing worse for South African cotton producers than being on the treadmill could be *not* being on the treadmill.

There are four major players competing for the spoils of agricultural innovation in South Africa: the innovator or technology supplier, the seed or germplasm supplier, the producer or farmer who buys inputs and the consumers, and the entity buying the agricultural product. These four parties and their share of the economic rent created by the introduction of Bt cotton will be discussed in turn in the next few sections.

The Innovator: Biotechnology Company Monsanto

Intellectual property rights have been reasonably well enforced in South Africa in a European-model court system that affords limited monopoly power, even in competitive markets, and increases the ability of investors and innovators to appropriate benefits created by their research effort (Traxler & Falck-Zepeda, 1999). Currently, the technology present in all the genetically engineered cotton varieties available for commercial production in South Africa belongs to only one company, Monsanto, which has a monopoly on the supply of the trait-producing genes. Monsanto has worked actively to license Bt to public and private companies in South Africa for other crops, but the company can set the technology fee for Bt cotton as a monopolist. Monsanto operates under a price ceiling, because there is a maximum effective price level it can charge. If the charged technology fee is too high, farmers can substitute conventional seed for Bt seed and use traditional pest control methods. As soon as farmers feel that the cost of Bt seed outweighs the benefits they receive, they will stop planting Bt seed and perhaps (as some have indicated) cotton altogether if conventional varieties are not profitable either. Figure 1 illustrates the share of additional income created by the introduction of the new technology that accrues to Monsanto.

The 2000/01 technology fee charged to large-scale farmers, R600 (US$86) per 25kg bag of seed, was higher than the fee charged to small-scale farmers, R230

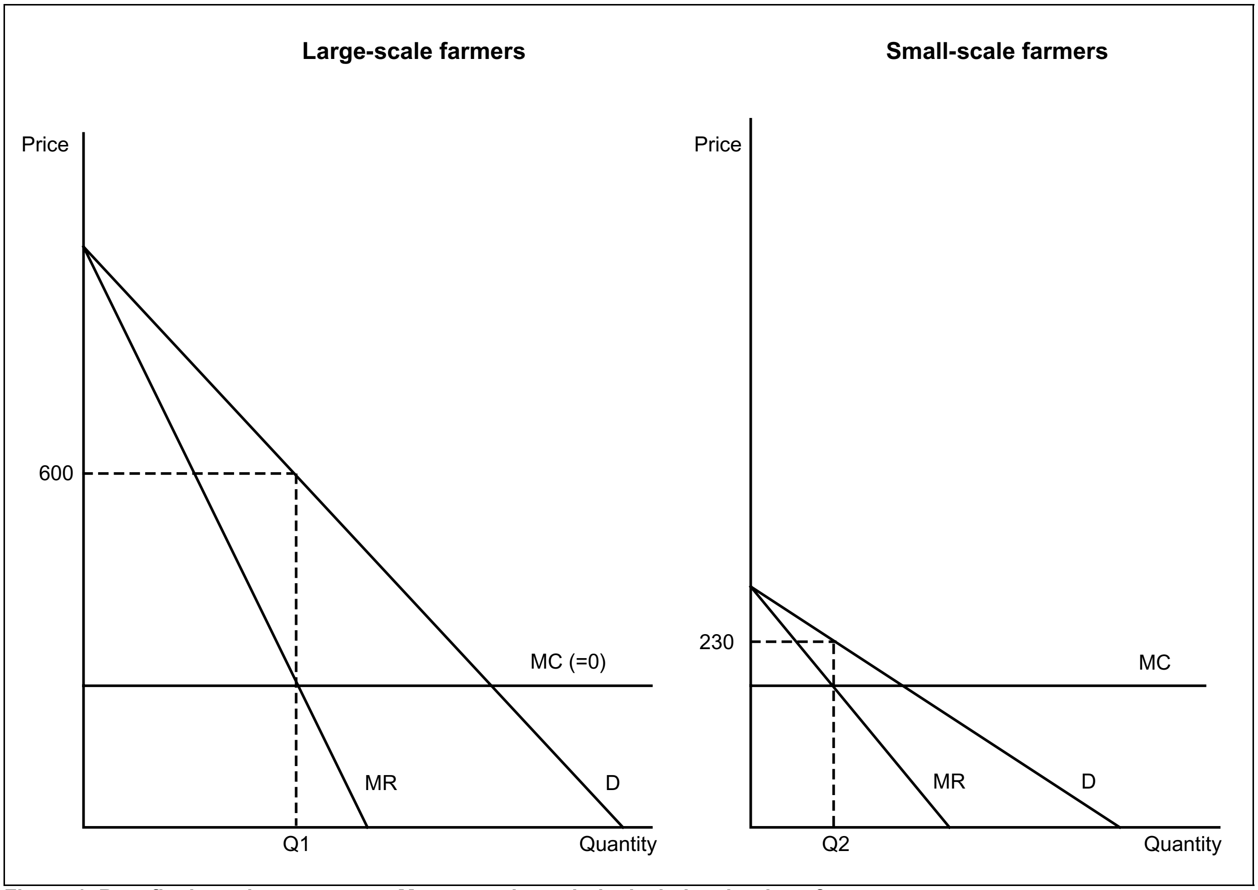

Figure 1. Benefit share that accrues to Monsanto through the levied technology fee.

(US$33) per 25kg bag, because of lower input demands and thus lower marginal revenue (Figure 1). Another factor that influenced the difference between the two prices in the initial stages of Bt cotton introduction in South Africa was that Monsanto wanted to establish a market with small-scale farmers, as the smallholder farming conditions are more applicable to the rest of Africa than that of the large-scale farmers. For Monsanto, the marginal cost of producing one extra unit of technology in South Africa is constant, because all the research and product development has already been done in the United States. The cost of having a product registered and taken through the SA biosafety protocol and regulatory requirements does not depend on the level of sales of the specific product. There is thus a zero marginal cost and perfectly elastic supply with the technology already on the shelf. The income benefit to Monsanto (and technology fee detriment to farmers) can thus be calculated simply by multiplying price by quantity. Arbitrage selling of seeds by small farmers to large farmers has been avoided, because the different farmer groups purchase their seeds at different outlets and transportation expenses are generally significant.

The Seed Supplier: Delta and Pineland

The cotton seed company Delta and Pineland (D&PL) has an arrangement with Monsanto for the sole right to use the Bt technology in their cotton seed. In 2000/01, D&PL charged approximately R25 per 25kg bag more for Bt cotton seed than for their conventional varieties. D&PL's share of the additional benefit created (and the seed cost detriment to farmers) is thus also straightforward to calculate by multiplying the R25 by the number of bags sold (Table 2, third row).

Sole right of distribution and an impressive adoption rate of the Bt technology have caused D&PL's market share in cotton seed sales to increase. Clark Cotton, a large ginning company, had most of the cotton seed market before D&PL's Bt introductions. For the 1997/98 season, D&PL introduced two Bt varieties (NuCotton 35B and NuCotton 37B). These two varieties were based on D&PL's older Acala 90 variety and were not

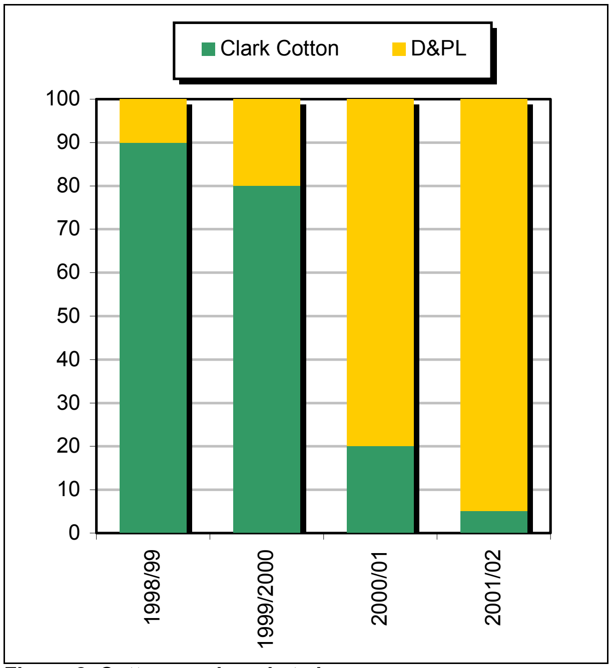

Figure 2. Cotton seed market share.
Note. Data from Clark Cotton and Cotton SA.

initially adopted with great enthusiasm; the newer Delta Opal, a non-Bt variety, was D&PL's more popular variety at the time. When NuOpal (Opal with Bt) was introduced for the 2000/01 season, D&PL captured a major share of the cotton seed market, as shown in Figure 2 (almost 80%). From conversations with surveyed large-scale farmers it appears that after paying R600 per bag of Bt seed to Monsanto, the additional R25 paid to D&PL for the new variety was insignificant.

Cotton Producers: Large- and Small-scale Farmers

South African cotton producers can be divided into two groups: large-scale, mainly white, farmers who produce under irrigated as well as dryland conditions, and small-scale, resource-poor, black farmers who produce dryland cotton. Not all the Bt adoption benefits enjoyed by these two groups of producers are straightforward calculations. Yield increases are the main source of additional income for farmers and are easy to calculate. Pesticide savings and reduction in application costs can also be estimated, but quantifying labor specifically for pest control is more difficult. Benefits such as peace of mind, managerial freedom (indicated by the large-scale farmers to be one of the biggest benefits of Bt cotton), and health benefits are not easy to measure either.

Table 1. Size of the yield increase per hectare.

	Q_1 (kg/ha w/ Bt cotton)	Q (kg/ha w/ conventional cotton)	$Q_1 - Q$ (kg/ha)	% yield increase
Large-scale farmers: irrigation	4,046	3,413	633	18.5%
Large-scale farmers: dryland	947	832	115	13.8%
Small-scale farmers: dryland	576	395	181	45.8%

Note. Data from Gouse, Kirsten, and Jenkins (2003). Yield differences are statistically significant at 95% confidence level.

Yield increases from the introduction of Bt cotton for large- and small-scale farmers shift their respective supply curves. If we classify the SA industry using the guidelines in Alston, Norton, and Pardey (1995) as an importer in a small open economy, and the introduction of Bt cotton has caused parallel outward shifts in the supply curves of both groups of farmers, then yield increases from farmer surveys can be added together. The per-hectare size of the respective yield increases are indicated in Table 1 and show that the increases in yield for large-scale farmers using irrigation was more than three times that obtained by small-scale farmers. Large-scale dryland farmers enjoyed the smallest yield gains.

The demand for seed cotton in South Africa is greater than domestic production even with these yield increases, so imports would have continued but would be reduced by the size of the yield gains. However, the hectares planted to cotton decreased, mainly due to low world cotton-lint prices. Therefore, even though per-hectare cotton yield increased, total cotton production decreased, and the size of cotton imports actually grew. Distributional impacts of depressed world seed cotton prices will be discussed later.

Besides yield benefits, the adoption of Bt cotton also caused a decrease in the volume of insecticides sprayed (and associated costs), because the Bt trait imparts insect resistance to the cotton plant. The income benefit to the cotton producer from lower input costs is an income loss to the pesticide supplier. Spraying less insecticide also means lower application costs. For large-scale farmers this is reflected in lower diesel costs and fewer tractor hours; for small-scale farmers the benefit is largely in labor savings. Because small-scale farmers do most farming activities by hand, reduced spraying usually means more time for weeding and other management practices. Walking with a knapsack sprayer on his back, a farmer has to cover a distance of 10–20 km to apply pesticide to one hectare of cotton. Water has to be carried by hand from communal water sources, and in dry areas clean water is a very scarce commodity. Illness due to exposure to pesticides is not uncommon among small-scale farmers (Ismaël, Bennett, Morse, & Buthelezi, 2002).

A high percentage of large-scale farmers have indicated that peace of mind about bollworms is a very important benefit of Bt cotton. Peace of mind about bollworms gave large farmers managerial freedom to devote time to other crops or general farming activities—the value of peace of mind might then be represented by the value of increased production of toher crops. Large-scale farmers also noticed increased populations of beneficial insects (such as ladybirds and lacewings) in Bt cotton fields, indicating a further possible benefit to the environment due to reduced insecticide applications.

Using only estimates for the value of yield, the cost of pesticides, seed costs, and technology fees, Table 2 shows that both large- and small-scale farmers realize increases in per-hectare income despite higher seed costs and the additional technology fee. The income advantage listed at the bottom of Table 2 could be considered a conservative estimate, because it does not include an application cost benefit or any value for peace of mind or managerial freedom. To the extent that reduced application costs benefit small farmers more than large ones, and managerial freedom impacts large farmers more than small ones, the differences between yield advantages in Table 2 could be greater or smaller if these factors were included.

The figures reported in Table 2 indicate that savings on chemical insecticides alone are not enough to offset the additional seed cost of Bt cotton seed. The size of the yield increase, linked to more efficient pest management using Bt varieties, is thus very important. Of course, yield benefits might vary substantially between seasons, depending on rainfall and insect pressure, but irrigated cotton that shows the highest income advantage has a more stable insect pest problem than experienced by dryland farmers. There will be seasons for dryland cotton when bollworm infestation levels are low; in those years it can be expected that the yield benefit of Bt cotton will be marginal. Our data for the 1999/2000 season showed a yield advantage for small-scale farmers in excess of 40%, but initial analysis of data collected on the Makhatini Flats during the dry 2002/03 season by the French research institute CIRAD in collaboration with the University of Pretoria showed no statistical significant yield difference (M. Fok & J.L. Hoffs, personal communication, January 2005).

Table 2. Summary of the income benefit to large and small-scale farmers (R/ha).

	Small-scale farmer	Large-scale farmer	
	Dryland	Dryland	Irrigation
Yield benefits per hectare @ R2.75/kg	498	314	1741
Reduced pesticides benefit	32	114	293
Increased seed and technology fee detriment	(163)	(234)	(419)[a]
Income advantage	367	194	1615

Note. Data from Gouse, Kirsten, and Jenkins (2003).
[a] Revised figure.

The Consumer or Buyer of Agricultural Output: Cotton Gins

Seed cotton is an intermediate input in the production of cotton fabrics and other cotton products. As there is no consumer or retail market for seed cotton, the cotton gins, as the "producers" of cotton lint, act as the consumers of seed cotton output. In South Africa there are four main ginning companies; Clark Cotton, the largest, has a market share estimated to be around 70% (C. Nolte, Clark Cotton, personal communication, August 2003). Clark Cotton is owned by AFGRI (formally known as OTK) and operates under the name of Vunisa Cotton in KwaZulu Natal and Swaziland. Clark Cotton also has gins in Zambia and Malawi and some ginning interests in other African countries.

There is some evidence that Clark Cotton might have some monopsony power influenced mainly by having a gin in (or very close to) each of the cotton-producing regions in South Africa. The profitability of ginning becomes marginal when cotton has to be transported over long distances, but because of lower world and import prices, as well as higher prices obtained for substitute crops such as maize and sunflower the last couple of seasons, SA cotton farmers have recently planted less cotton. There are reports that Clark Cotton has imported cotton from surrounding countries at a lower price than the Cotlook A Index (Calcaterra & Poonyth, 2001, and discussion with Cotton SA), but their monopsony power is a moot issue because of inconsistent seed cotton production both at

Table 3. Distribution of additional benefit according to farmer group.

	Small-scale dryland farmers	Large-scale dryland farmers	Large-scale irrigation farmers
Seed company: D&PL	3%	2%	1%
Technology supplier: Monsanto	28%	52%	20%
Farmer	69%	45%	79%
Consumer: ginning companies	0%	0%	0%

Note. Percentages calculated using production budgets in Gouse, Kirsten, and Jenkins (2003).

home and in surrounding countries. Cotton gins need to have a consistent supply of cotton to cover their substantial fixed property, plant, and equipment expenses; drought conditions and political instability in the region leaves Clark Cotton with little benefit from the Bt technology.

Welfare Distribution

The previous sections show that the sum of the value of additional yields and insecticide cost savings (Table 2) can be taken as a quantifiable benefit to farmers from the introduction of Bt cotton. After subtracting from this benefit the increased seed costs and technology fees that go to the seed supplier and the technology developer, respectively, the increase in farmer welfare can be measured as additional income from the introduction of the new technology. The distribution of this income can be determined from the average production budgets of each farmer group; these results are summarized in Table 3.

Even though large-scale dryland farmers are able to produce cotton more efficiently than small-scale farmers due to better management, mechanization, and use of fertilizer, small-scale farmers capture a larger share of the welfare gain because they pay a lower technology fee and obtain higher yield benefits. Large-scale irrigation farmers capture the largest gains because of substantially higher yields. Because world cotton prices are unaffected by SA production, yield increases in South Africa do not transmit down to consumers as they would if increased output led to lower prices. Based on the pesticide savings indicated by surveyed farmers, the insecticide suppliers lost approximately 1.9 million South African Rand during the 2000/01 season alone because of reduced use of pesticides with Bt cotton.

Income distribution can also be calculated from the aggregate monetary value created on the total area planted under Bt cotton. Making use of 2000/01 cotton industry figures for this calculation and assuming seeding rates of 11.5, 8, and 20 kg/ha for small-scale, large-scale dryland, and irrigation farmers, respectively, the welfare distribution is shown in Table 4. These figures compare well with the percentages in Table 3 that were calculated from average household budgets for the same farmer groups. Small-scale farmers do not benefit as much in the aggregate calculation (Table 4), but this is likely due to underrepresentation of small farmers in the aggregate data. The decrease in monetary value of pesticides used by each group (and revenue lost by pesticide companies) is also included and gives some indication of the value that large farmers place on the previously discussed peace-of-mind factor. In many cases, pesticides are applied by large farmers in program spraying that is determined before insect pressure is determined. Small farmers usually only apply pesticides post emergence.

To explore the sensitivity of the welfare distribution results to different assumptions concerning seeding rates, Table 5 provides some comparisons. If small-scale farmers have as high a seeding rate as some suspect, their welfare share might be lower than that indicated in Table 4, which is based on the seeding rate used by Ismaël et al. (2001). Almost doubling the seeding rate used by small farmers and not increasing their yields only reduces the benefits accruing to them by 15%. The last column in Table 5 considers the possible impact of a change in Monsanto's policy concerning the technology fee paid by small-scale farmers and shows that their welfare share would still be almost 50% if they had to pay the same technology fee as large-scale farmers and were seeding at the lower rate.

Conclusion

The analysis here shows that the foreign multinational corporation Monsanto that has introduced Bt cotton in South Africa benefits from the introduction. More surprising is that different farmer groups in South Africa are benefiting more than the technology developer. In fact, small-scale farmers benefit more than larger scale dryland farmers in the survey data. The reverse is true when aggregate cotton industry data for the country is considered, but this is likely due to underrepresentation of small farmers in the industry data. Large-scale irrigation farmers benefit more than either of the other farmer groups from both survey and industry points of view.

Table 4. Value of benefits to aggregate cotton industry groups for the 2000/01 season (current SA Rand).

	Small-scale dryland farmers	Large-scale dryland farmers	Large-scale irrigation farmers	Total
Seed company: D&PL	32,546	54,576	74,156	161,278
Technology supplier: Monsanto	299,425	1,309,824	1,779,744	3,870,676
Farmer	1,038,647	1,323,468	5,988,097	8,350,212
Pesticide companies[a]	-90,563	-777,708	-1,086,385	-1,954,656

Note. Values calculated using cotton area planted, seeding rates, seed costs, technology fees, and insecticide saving data in Gouse, Kirsten, and Jenkins (2003).
[a] Revenue lost by pesticide companies.

Table 5. Distribution of benefits for small-scale farmers under different seeding rate scenarios and technology fees (in SA Rand).

	Small-scale dryland farmers with a 11.5 kg/ha seeding rate	Small-scale dryland farmers with a 20 kg/ha seeding rate	Small-scale dryland farmers paying R600/bag technology fee and planting 11.5 kg/ha seed
Seed company: D&PL	32,546 (2%)	56,602 (4%)	32,546 (2%)
Technology supplier: Monsanto	299,425 (20%)	520,738 (35%)	781,108 (52%)
Farmer	1,167,982 (78%)	922,613 (62%)	686,299 (46%)

These results were far from a foregone conclusion with farmers contending with two monopolists on the input side and a dormant monopsonist on the output side in the South African cotton industry.

With the spread of Bt technology and herbicide-tolerant varieties, and new innovations in the pipeline (such as stacked gene varieties), South African farmers will be weighing the costs and benefits of adopting the new varieties that in the past have been influenced by different factors for each of the groups of farmers. The Bt technology has had a substantially positive impact on the cotton industry in South Africa; it is clear that both the commercial and smallholder sectors in South Africa can benefit. It is probably small-scale cotton farmers that are hit the hardest by low world cotton prices, and the Bt technology might be helping these small cotton farmers survive the price squeeze.

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