BT Cotton in South Africa: Adoption and the impact on farm incomes amongst small-scale and large scale farmers

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BT COTTON IN SOUTH AFRICA: ADOPTION AND THE IMPACT ON FARM INCOMES AMONGST SMALL-SCALE AND LARGE SCALE FARMERS [1)]

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1 Introduction

South Africa is one of few developing countries, and the only one in Africa that has adopted genetically modified crops for commercial production. Insect-resistant cotton has been produced since the 1997/1998 season and insect-resistant yellow maize since the 1998/1999 season. For the 2001/2002-season herbicide tolerant cotton has been made available for commercial production and herbicide tolerant soybeans have been introduced on a small scale. Insect-resistant white maize has also been released in limited quantities.

Farmers have met the introduction of insect-resistant cotton with reactions varying from blind enthusiasm and cautious pessimism to downright disregard. This paper will focus on the reasons and effects of Bt cotton adoption by large-scale and small-scale cotton farmers in South Africa. Section 2 gives a profile of the large-scale and small-scale farmers surveyed. Section 3 compares the reasons for adoption between the two farmer categories; section 4 looks at the impact of the adoption on yields, cost and profit; section 5 discusses the production efficiency effects of adopters and non-adopters in the two farmer groups and section 6 concludes the discussion.

2 Profile of South African cotton farmers

According to the May 2002 crop estimate of Cotton SA, the total seed cotton production for the 2001/2002 season will reach only 96 501 bales, a reduction of 46% on the 2000 / 2001 season's production. The poor price prospects at planting time and the more attractive prices of competing crops like maize and sunflower have motivated commercial farmers to plant less cotton. The area planted to cotton under irrigation fell by 49% and the dry land area fell by 42%.

In the 2000/2001 season an estimated 300 large-scale commercial farmers produced 95% of South Africa's cotton crop. The other 5% were produced by about 3 000 smallholder farmers on the Makhathini Flats and a further 312 smallholders in the Tonga area (Cotton SA, 2002). A total of 157 515 bales (200kg each) were produced on 56 692 hectares, with smallholders contributing a total of 7 300 bales (4.6%).

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2.1 Large-scale cotton farmers

The majority of large-scale cotton production takes place in 6 production areas in South Africa. The most important dryland production areas are: the Springbok Flats in the Limpopo Province and in the Dwaalboom region in the North West. Irrigated cotton is produced around the towns of Marble Hall and Groblersdal and on the Loskop irrigation scheme in Mpumalanga, at Weipe next to the Limpopo River in the Northern Province and in the Northern Cape and Orange River area. There are also some large-scale farmers in the Pongola district close to the Makhathini Flats in Northern Kwa-Zulu Natal (Table 1 shows the areas planted). Farmers surveyed on the Springbok flats planted between 85 and 550 hectares of cotton, irrigation farmers in the Groblersdal area plant between 20 and 160 hectares on average, with the farmers in the Northern Cape planting an average of 30 hectares.

Table 1: Cotton Production distribution in South Africa - 2001/2002 Production Year

Area	Hectares Irrigation	Hectares Dryland
Mpumalanga	4 322	0
Limpopo Province	3 071	12 515
Northern Cape and Orange River	1 214	0
KwaZulu Natal	620	6 843
North West	224	2 747
Total	**9 451**	**22 105**

Source: Cotton SA

Cotton farmers on and around the Loskop irrigation scheme produce cotton in addition to their other farming enterprises such as export table grapes, citrus, deciduous fruit and vegetables. The main farming activities of the farmers in the Northern Cape are viticulture and the production of groundnuts. Most irrigation farmers in Mpumalanga and the Northern Cape rotate or substitute maize and cotton in the summer and produce wheat in the winter. On the Springbok flats cotton is rotated with maize and sunflower. In most of the production areas cotton is usually not the dominant enterprise and is produced in combination with other crops. The choice of enterprise is usually determined by the rotation requirements of the soil and the relative prices of the competing enterprises. The recent high prices for maize would mean that more farmers would favour planting maize instead of cotton.

The large-scale farmers included in the study were from the irrigation areas in the Northern Cape, Mpumalanga as well as some dryland farmers on the Springbok flats in the Limpopo Province. All of these farmers were surveyed during 2001. Budgets and other information were also obtained from the Clark Cotton ginnery branches across the country.

2.2 Small-scale cotton farmers

Despite various land reform projects attempting to settle small-scale cotton farmers in established cotton production areas the traditional small-scale cotton production areas of Tonga in Mpumalanga and Makhathini in northern KwaZulu Natal remain the major contributors.

Currently there are more than 40 farmer organizations on the Makhathini Flats, with membership varying between 15 and 300. The area under cotton production and the number of cotton producers depend on the availability of production credit and the price of cotton. It is estimated that 4 500 cotton farmers could potentially be active in the Makhathini area planting on average between 1 and 3 hectares of rain fed cotton. Depending on credit availability and the price of seed cotton, between 2 500 and 10000 ha of cotton is planted (Bennet, 2001). An estimated 6 000 hectares were planted in 2001/2002 and it is expected that the share of smallholders in the total seed cotton production will again rise this year - albeit only because of a drop in commercial production. Role-players in the cotton industry envisage that small-scale farmers could produce up to 30% of the total cotton crop in South Africa by the year 2005 (Cotton SA, 1998). Whilst large-scale irrigation farmers can substitute or rotate cotton with maize, vegetables or groundnuts and large-scale dryland farmers, with less severe climatic conditions, can plant sunflower or maize, small-scale cotton farmers on the Makhathini are dependent on cotton, because of low, irregular rainfall and a lack of production credit for other crops. The Makhathini Flats is said to be one of the best, if not the best agricultural areas in South Africa. The area has a deep, very fertile soil and has an enormous (currently unutilised) irrigation potential – being situated under the Jozini dam.

Until the 2000/2001 season, the Vunisa Cotton company (part of Clark Cotton – owned by OTK Holdings Ltd) has been the main ginnery and "life source" active on the Makhathini Flats. By managing and facilitating production credit supplied by the Land Bank, distributing production inputs on account, and by supplying production information and assistance through extension officers, Vunisa has made a major contribution to the success story of the cotton farmers on the Makhathini Flats.

Data on small-scale farmers used in this paper was gathered on the Makhathini Flats through a survey in November 2000 by the University of Reading in collaboration with the University of Pretoria (Ismael et al, 2001).

3 Reasons for adoption of Bt cotton

The Makhathini Flats have shown an increase in the adoption of Bt cotton from 7% in 1997/1998 to 75% in 1999/2000 (DFID, 2001). An adoption of between 80% and 90% was expected for the 2000/2001 season and the same for the 2001/2002 season. (Van Jaarsveld, 2002). More than 95% of the cotton produced in the Tonga area (just North of Swaziland, next to the border with Mozambique) is insect-resistant (Anthony, 2002).

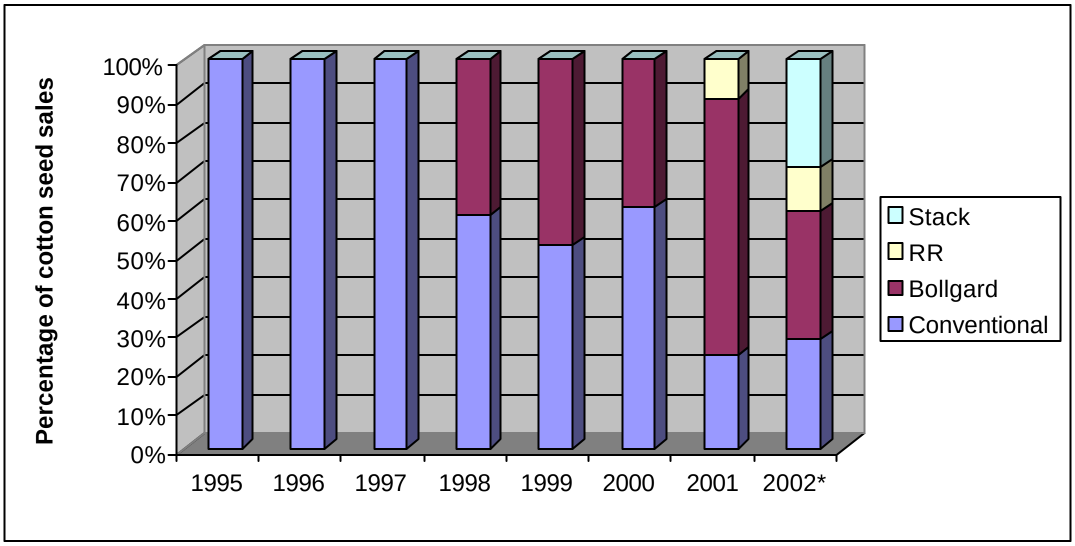

Figure 1: Adoption of new cotton seed varieties (*Estimation)
Source: Cotton SA, Journal to the Cotton Industry

From the cotton seed sales in Figure 1 it is clear that cotton farmers have reacted positively to the introduction of genetically modified cotton seed with almost 80% of cotton seed used being genetically modified seed. Bollgard or Bt seed is the insect-resistant seed with resistance to bollworms. RR is Roundup Ready, the herbicide-tolerant variety and the Stacked-gene varieties contain both the Bt and the RR genes.

3.1 Reasons for adoption: Large-scale farmers

In an analysis using our current large-scale farmer data set, factors such as area planted, age, education and credit did not render significant results as reasons of adoption. Later studies will focus more on this aspect. For the purpose of this paper we hypothesise that the perceived and real benefits as indicated by seed agents and observed through own cotton production experience can be accepted as partial reasons for adoption of the new technology. In Table 2 the "Most important" column indicates the most important reasons of adoption or benefits as indicated by surveyed large-scale farmers. The "Specific benefit" column indicates all the benefits of Bt cotton as indicated by large-scale farmers and the percentage of farmers that indicated the specific benefits.

Table 2: Benefits of Bt-cotton as indicated by large-scale cotton farmers

Benefits and reasons for adoption	Most important reason / benefit (% of farmers)	Specific benefit (% of farmers)
Increased yield	7%	52%
Pesticide saving	39%	62%
Better crop and risk	18%	72%
Better boll worm control	9%	55%
Peace of mind about bollworms	25%	77%
Labour saving	0%	2%
Better for environment	0%	37%
Other		9%

All the commercial farmers surveyed had planted insect-resistant cotton in the current season or in the past. Of the 43 large-scale farmers interviewed, 39% indicated that the most important benefit of Bt cotton is the saving on pesticides and application cost. Peace of mind about bollworms came in as the second biggest reason for adoption with 25% of farmers indicating the benefit as most important. When asked to indicate all the benefits of insect-resistant cotton, 77% of farmers indicated peace of mind and 72% indicated better crop and risk management as a benefit. All the large-scale farmers surveyed were involved with other farming activities during the cotton season. Therefore, the large indication of peace of mind is not surprising. Using hired labour, scouting and spraying is especially difficult over the Christmas - New Year period and this is a crucial time in the production cycle of cotton in South Africa. The very low labour saving perception can indicate that farmers feel that pesticide application is more capital- than labour intensive.

When asked about the disadvantages of Bt-cotton the prominent answer was the cost of seed and the technology fee. This is also the reason why some farmers have stopped planting Bt-seed. Large-scale farmers try to stretch a 25kg bag of Bt-seed as far as possible using precision planters. A 25kg bag of Bt-seed costs around R210 ($21) with an additional R600 ($60) technology fee. A farmer planting 20kg of seed per hectare indirectly spends R 480 (US$ 48) on bollworm control. Some commercial farmers who have already invested in spraying machinery feel that they can control bollworms for less. Most farmers don’t spend R480 / ha on the control of bollworms in a normal year but when worm pressure is high, chemical and application costs can easily exceed this additional fee. In the 2001/2002 season, Monsanto, in alliance with Delta Pine, implemented a possibly more acceptable technology fee payment system. Farmers can now pay R400/ha ($40) technology fee for irrigation land and R120/ha ($12) for dryland, on the condition that they present a GPS map of the planned cotton field. The R600/bag ($60) technology fee system is also still available for farmers to use so a farmer can decide which option is the most cost effective for him.

3.2 Reasons for adoption: Small-scale farmers

The impressive increase in adoption of Bt cotton by small-scale farmers from 7% in 1997/1998 to around 90% in the 2001/2002 season can mainly be attributed to the success of the farmers who first adopted the new technology (Ismaël et al, 2001). Looking at the benefits indicated by the adopters and the perceived benefits indicated by the then non-adopters, it is interesting to compare the perceptions about Bt cotton before and after the adoption. While 32% of non-adopters indicated that a yield increase is the most important benefit of Bt-cotton, increased yield was only indicated as the most important benefit by 18% of adopters. Increased yield is still indicated as a reason by more than 58% of adopters, but it seems that the most important benefit of Bt-cotton after adoption has become pesticide saving. In rural areas where infrastructure, transport and services are almost non-existent, managing pest infestation in crops is a major problem. In Table 3 the “Most important benefits” column indicates the percentage of farmers that indicated the various benefits as most important, while the “Specific benefit” column indicates all the benefits indicated by farmers.

Table 3: Benefits of Bt cotton as indicated by small-scale farmers

Real and perceived benefits	Most important benefit (% of farmers)		Specific benefit (% of farmers)	
	Non-adopters	Adopters	Non-adopters	Adopters
Increased yield	32%	18%	62%	58%
Better quality cotton	5%	3%	12%	30%
Higher price for cotton	0%	1%	12%	15%
Pesticide saving	35%	50%	77%	70%
Labour saving	10%	10%	42%	35%
Application saving	5%	3%	30%	18%
Other	10%	13%	27%	40%

3.3 Difference in adoption behaviour between large-scale and small-scale farmers

In comparison to small-scale farmers, the increased yield benefit seems to be not that important to large-scale farmers. Although more than 50% of large-scale farmers indicated increased yield as a benefit, it is seen more as a bonus. The big advantage for large-scale farmers is that insect-resistant cotton gives them the peace of mind and the managerial freedom to go on with other farming activities. As previously mentioned, the whole process of pesticide application is more capital and management intensive than labour intensive for large-scale farmers. Large-scale farmers have to hire an aeroplane or use their own tractors to apply pesticides. The difficulty lies in fitting sprays in between the rain and irrigation schedules.

The large percentage of small-scale farmers indicating that pesticide saving is the most important benefit is not really surprising. When one includes saving on application cost, and labour saving with pesticide saving, more than 63% of small-scale Bt-adopters agree on the entire bollworm control benefit of Bt-cotton. Pesticide application implies huge difficulties for small-scale cotton farmers: with a low level of education amongst small-scale farmers, problems with the mixing of pesticides and calibration of knapsack sprayers for different pesticides cause concern about the real efficacy and effectiveness of pesticide application. Applying pesticides is very much a labour intensive action for small-scale farmers. Walking with a knapsack sprayer on his back a farmer has to cover a distance of between 10 and 20 kilometres per hectare and taking almost a day to complete the task. Water has to be fetched from communal water points and in addition water (especially in the Tonga community) is a very scarce commodity and has to be fetched with water trucks or any other transport available. By the time a farmer has noticed bollworms, bought his pesticides and started to spray, severe damage has already been done. Both large and small-scale farmers still have to spray for other problem insects like jassids and aphids, as these pests are not controlled by Bt cotton. These pests are now becoming the main cotton pests.

Large-scale cotton farmers have indicated other indirect benefits of Bt-cotton. Spraying less pesticide or none at all has caused predator insects to flourish. More than 46% of farmers have noticed more beneficial insects on their Bt-cotton fields.

Some farmers in the Northern Cape have indicated that Lady Bird beetles and Lacewings have reduced aphid populations to such a level that farmers do not need to spray for aphids on winter wheat anymore. In the past some farmers in the Groblersdal area have experienced some pesticide resistance with bollworms. For them Bt-cotton is a much needed solution. In seasons where bollworm pressure is high, farmers are forced to use Pyrethroids, killing all beneficial insects and causing Red Spider Mites to thrive. Chemical control of Red Spider Mites is very expensive.

4 Impact on farm income

The adoption of Bt-cotton impacts on farm income in mainly 3 ways:

- Decrease in input cost through savings on pesticide chemicals and application costs
- Increase in input cost through higher seed price and an additional technology fee
- Increase in yield

Each of theses are discussed subsequently:

4.1 Yield effects

The average cotton yield of adopters was significantly higher than that of non-adopters for both the large-scale and small-scale farmers (Table 4).

Table 4: Significance of the difference between average yield per hectare for adopters and non-adopters

	Mean difference	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference		t-stat
				Lower	Upper	
Large-scale*	540.55	429.26	129.43	252.17	828.93	4.176
Small-scale	179.60	539.95	85.37	6.92	352.28	2.104

**Large-scale farmers include irrigation and dryland farmers*

According to the innovator of the new technology (Monsanto) the yield advantage of Bt cotton can be mainly attributed to the fact that bollworm infestations are managed in a more effective manner than can be done with conventional spraying programs. With Bt cotton the worms are killed before any significant damage can be done. With conventional cotton, farmers only spray for bollworms when scouting indicates a worm infestation above a certain level and by that time yield-reducing damage has already been inflicted. Table 5 indicates the yield differences between adopters and non-adopters for large and small-scale farmers under different production conditions. All the following figures are based on the 2000/2001 production season for the surveyed large-scale farmers and on the 1999/2000 season for the small-scale farmers.

Table 5: Comparing the average yield per hectare of large-scale and small-scale adopters and non-adopters according to irrigation practice.

		Non-Bt Small-holder 1999/2000 (kg/ha)	Bt Small-holder 1999/2000 (kg/ha)	Non-Bt Large-scale 2000/2001 (kg/ha)	Bt Large-scale 2000/2001 (kg/ha)
Irrigation	Mean			3413	4046

	Std. Dev			1372	1210
Dryland	Mean	395	576	832	947
	Std. Dev	389	547	56	66

Large-scale adopters producing under irrigation on average realised a yield of 633 kilograms per hectare higher than that of the non-adopters. For large-scale farmers producing under dryland conditions there was an average yield benefit of 115 kilograms per hectare and for the small-scale adopters an average benefit of 181 kilograms.

4.2 Cost effects

It is normally argued that the Bt technology would save costs mainly through lower application levels of pesticides. Table 6 reflects the costs of pesticides as used by adopters and non-adopters.

Table 6: Comparing the cost of applied pesticides for non-adopters versus adopters

		Non-Bt Small-holder 1999/2000 (R/ha)	Bt Small-holder 1999/2000 (R/ha)	Non-Bt Large-scale 2000/2001 (R/ha)	Bt Large-scale 2000/2001 (R/ha)
Irrigation	Mean			519.15	226.24
	Std. Deviation			183.51	79.89
Dry	Mean	129.13	96.96	192.33	78.50
	Std. Deviation	72.05	101.87	56.54	82.73

4.3 Impact on net farm income.

Despite a higher seed cost and the additional technology fee, both large-scale and small-scale farmers realise higher net incomes per hectare due to the higher yield and savings on pesticide chemicals (Table 7). This income benefit will increase even more when cost of application is taken into account. The advantage of less chemical application for small-scale farmers is both financial and health related. Less labour needed, less water transport and less exposure to toxic chemicals. Large-scale farmers save on fuel, repairs and maintenance or on flying costs. There is also less tractor traffic in the cotton fields, causing indirect benefits to soil quality.

Table 7: Income effect of adoption of Bt-cotton

	Small-scale farmer	Large-scale farmer	
	Dryland (R/ha)	Dryland (R/ha)	Irrigation (R/ha)
Yield Benefits per hectare @ R2.75/kg	498.19	314.44	1740.75
Reduced pesticides benefit	32.17	113.83	292.91
Increased seed and technology fee detriment	(163.08)	(234.17)	(570.23)
Income advantage / disadvantage	367.28	194.10	1463.43

Despite the fact that large-scale dryland farmers use almost 50% less seed per hectare than the small-scale farmers the additional seed and technology cost of large-scale dryland farmers are higher than that of the small-scale farmers. This is due to the fact that small-scale farmers pay only R230 technology fee per bag while the large-scale farmers pay R600 per bag. The lower price for small-scale farmers can be explained by a combination of factors including willingness to pay, an effort of poverty elevation by the multinational technology innovator and the establishment of a market for transgenic cotton for small-scale producers. These factors will be further investigated in later studies.

5 Efficiency analysis of Bt-cotton

In addition to the monetary measures of success in adopting Bt cotton, we also explored the technical efficiency of the large-scale cotton producers (this is similar to the analysis for small-scale farmers on the Makhatini Flats reported in Beyers, *et al.* (2002)). For this purpose, the data envelopment analysis (DEA) model, that has been widely applied to efficiency measurement problems, was used in this study. The model used for measuring farm-level efficiency follows the framework introduced by Farrell (1957) and extended by Fare et al, (1985), to include the decomposition of overall efficiency into measures of technical and scale efficiency. The method is non-parametric and deterministic, with the best practice frontier constructed by minimising inputs per unit of output. Then, the efficiency of each farm is measured as a ratio of actual to best practice performance. Therefore, the sources of inefficiency can be identified and policies to procure efficient production can consider these findings. The basic DEA efficiency results are extended by decomposing the efficiency measures into pure technical efficiency and scale efficiency. Then each scale inefficient farm is classified as being too small or too large.

The data is comprised of three groups: 9 farmers in 1998/99; 15 farmers in 1999/2000; and 39 farmers in 2000/01. Due to these small sample sizes, irrigated and dryland cotton was group together in this study. In the case of more sizable samples, a distinction can and should be made between the dryland and irrigation farmers.

The adopters are far more technically efficient, on average, than the non-adopters. The 1998/99 efficiency frontier is defined by one farm - an adopter (again, bearing in mind the small sample). The returns to scale results show that apart from this efficient farm, which has an overall efficiency score of unity, and is scale efficient by definition (shown as constant returns to scale, CRS), all but one of the enterprises are too small.

Table 8: DEA results for large-scale cotton farmers for 3 seasons

	Efficiency			Frontier	Returns to Scale		
	Total	Technical	Scale	farms (#)	IRS	CRS	DRS
		Season 1: 1998 / 1999					
Mean: Total sample	0.78	0.91	0.86	1	7	1	1
Mean: Non-Adopters	0.72	0.84	0.86	0	4	0	1
Mean: Adopters	0.84	0.99	0.85	1	3	1	0
		Season 2: 1999 / 2000					
Mean: Total sample	0.67	0.79	0.85	3	12	3	0
Mean: Non-Adopters	0.65	0.73	0.89	2	6	2	0
Mean: Adopters	0.69	0.86	0.80	1	6	1	0
		Season 3: 2000 / 2001					
Mean: Total sample	0.45	0.65	0.69	6	33	6	0
Mean: Non-Adopters	0.37	0.63	0.59	2	14	2	0
Mean: Adopters	0.51	0.67	0.76	4	19	4	0

In the second season, reported in the lower section of Table 8, the first column shows that the mean total efficiency was a little lower at 0.67. Again, the adopters have a higher average efficiency level of 0.69 compared to that of the non-adopters of 0.65. The pure technical efficiency level of the adopters is higher than for the non-adopters, whilst most of the non-adopters' advantage is attributed to the scale of their operations. In this season, three farms define the frontier. The dominant problem is still that 84% of the farms are too small. These results should be viewed with the nature of the second season in mind: many of the commercial farmers were unhappy with the initial Bt-cotton seed and thought the technology fee too high during times when there was not worm pressure. In addition, they had to spray for other pests, and would then rather use conventional seed and pesticides.

In the third season the balance swayed in favour of Bt-cotton. Sixty-seven percent of the efficient farms were characterised by the use of Bt-cotton. The adopters represented fifty-eight percent of the sample in that season. This can partly be ascribed to the development in the seed technology where the Bt gene was added to the Opal variety (in stead of Akala 90 of the previous season), which is the preferred variety. The lower efficiency scores are ascribed to the substantial group of newcomers who faced the technology for the first time. In this season the adopters are more efficient than the non-adopters in terms of technical performance and returns to scale.

In comparison with results from the small-scale farmer study, (Beyers, et. al., 2002), the commercial farmers operated at much higher levels of total efficiency than the small-scale farmers in both the 1998/1999- and 1999/2000 seasons. The first season results show that both small-scale and commercial non-adopters were 84% technically efficient. However, in the case of adopters the small-scale farmers were 77% technically efficient compared to the commercial farmers' 99% technical efficiency. A reversal occurred in the second season where small-scale non-adopters were more efficient than their commercial counterparts. Commercial adopters, however, were 86% efficient, compared to small-scale adopters' 79% technical efficiency. While commercial farmers were on average more scale efficient than small-scale farmers, the latter group's adopters had higher scale efficiency scores in the second season than that of the commercial adopters. Also, in terms of defining the frontier, a higher percentage of commercial farmers constituted the efficiency frontier (15% on average) as opposed to the small-scale group (8% on average). This may well be confirmation that the small-scale farmers are lacking information and training on the precise use and benefits of the Bt-technology.

6 Conclusion

The very impressive adoption rate of insect-resistant cotton in South Africa can be attributed to different benefits enjoyed by adopters. Both large-scale and small-scale farmers enjoy financial benefits due to higher yields and despite higher seed costs. In addition, those who adopted the technology appear to be more technically efficient than those who do not adopt – indicating that it is perhaps the better farmers who spot the potential benefits of the Bt cotton seed. It is encouraging to hear reports of cross-pest control improvements due to less spraying in the commercial areas – this was not true for the smallholders. Continued research on diverse benefits and the distributional impact of the technology are underway and promise to deliver interesting results on the various impacts Bt cotton is having on the South African cotton industry.

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