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Acreege Response Before and After the Deregulation of the South African Maize Industry:  
The Role of SAFEX in Price Discovery and Price Risk Management

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## Abstract

*The withdrawal of the Maize Board in 1996 meant that farmers could no longer rely on their pre-planting price or "voorskat" for price discovery and price risk management. Some have claimed (UNCTAD, 2007) that the South African Futures Exchange (SAFEX) can provide these functions. We test this claim and analyse the implications of it. To do so, we build on an acreage response model developed earlier by Chavas and Holt (1990) by allowing for a futures market as well as accounting for farmer heterogeneity and the relative impact of price risk and yield risk. We first establish farmers' responsiveness to risk by determining their risk aversion and, more specifically, whether they exhibit decreasing aggregate risk aversion (DARA). We find that farmers are risk averse and display positive wealth effects, which may be due to DARA. We can say little about how farmers have reacted to the price discovery function of expected prices both before and after the withdrawal of the Maize Board. However, we can conclude that farmers have responded less to price risk post-1996, even though prices were more volatile during this period. This supports UNCTAD's (2007) claim. Combined with the finding of positive wealth effects the policy implication is that an improvement in the financial position of farmers as well as their access to futures markets can help reduce the impact and disutility of risk and, hence, improve their welfare.*

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## **I Introduction**

Between 1937 and 1996 all aspects of maize marketing in South Africa were controlled by the Maize Board. Their pre-planting price simultaneously reduced price risk and provided a price discovery service. Since the Maize Board's withdrawal in 1996, these services are said to have been provided for farmers by the South African Futures Exchange (SAFEX) (UNCTAD, 2007). This paper aims to test the claim theoretically and empirically. If this claim is true then policy makers hoping to improve the income security of poorer farmers can be confident that SAFEX is a sufficient tool to achieve this goal, rendering regulation unnecessary.

Methodologically, the study is rooted in an earlier paper by Chavas and Holt (1990), which derived a general acreage response function from the maximisation of farm household expected utility. Their model estimates the optimal acreage function using aggregate data for two crops in the presence of uncertainty. This paper extends the Chavas and Holt (1990) approach by allowing for a futures market and farm heterogeneity, and by distinguishing between yield and price variance. While we develop our theoretical model for several crops, our econometric model is for maize only. We then estimate this model using a panel consisting of aggregate provincial-level data over the period 1971-2008.

We use this model to answer three questions.

- i) Are South African maize farmers risk averse and, if so, do they exhibit decreasing aggregate risk aversion (DARA)?
- ii) Have farmers' acreage responses to expected prices changed since the withdrawal of the Maize Board?
- iii) Has farmers' ability to manage price risk changed since the withdrawal of the Maize Board?

The answers to these questions allow insight into the effects of local agriculture's transition from regulation to a free-market system and into the income security of farmers.

While earlier research has used survey data to analyse the behaviour of South African maize farmers with respect to hedging instruments (Jordaan and Growe, 2007; Ueckermann et al, 2008 and

Woolverton and Skyuta, 2009), it has not compared the use and effectiveness of these instruments to the services offered by the Maize Board. Longitudinal survey data over the period of interest is not available, but the use of a panel across South African regions can help us to understand the changing behaviour of farmers over time while also accounting for certain farmer heterogeneities. To our knowledge an acreage response model has never included the option of futures markets or been estimated using panel data.

Our analysis indicates that farmers are risk averse and display significant positive wealth effects, which are necessary, but not sufficient for DARA preferences. In other words, the decisions made by wealthy farmers are less susceptible to risk than those of poor ones.

With respect to price discovery, there is little firm evidence to suggest that farmers respond positively to higher expected prices, whether established by the “*voorskot*” under the Maize Board or the futures price after its withdrawal.

In terms of price risk management, however, we are confident that SAFEX has allowed for farmers to deal with increased price volatility subsequent to the withdrawal of the Maize Board. However, we find that yield risk has at least as significant an impact on farmers’ decisions as price risk.

We create perspective for our analysis by describing the background of the Maize Board, its operations, and the subsequent introduction of SAFEX. We then review the literature on price discovery and price risk management in agriculture in the context of uncertainty. With this literature in mind, we develop a theoretical and econometric model, which is used to address the three questions posed earlier. After estimating this model, we conclude by suggesting some policy implications regarding the income security of developing farmers.

## II Background

Despite a difficult start to the 20<sup>th</sup> century with the recovery from the Boer War and the internal unrest in 1914/15, South Africa's agricultural production rose steadily after World War I. However, prices were unstable (particularly those of wheat and maize), marketing was disorderly and the depression brought on a lack of credit. Some even argued that farming in South Africa had degenerated into *Räuberwirtschaft* (Houghton, 1973: 58). Producers blamed inadequate marketing infrastructure and speculators, and argued for co-operative societies as a solution (De Swardt, 1983: 5).

Co-operatives for various farm products existed in some parts of the country, but not at a national scale. In 1922, however, the Co-operative Act was passed, allowing for government supervision and guidance in the establishment and running of co-operatives. Farmers were now offered a pre-planting price or "*voorskot*", while larger producers could still try to negotiate a better price by negotiating directly with the millers and exporters and delivering directly to elevators. Co-operatives grew and expanded, while Land Bank financing allowed for improvements in marketing infrastructure. This was a period of high expectations for co-operatives as a solution to market instability (De Swardt, 1983: 5-10).

While the system worked reasonably in normal times, it came under pressure when the Great Depression began and prices dropped. Co-operatives were forced to buy up increasing volumes of maize until, by 1933, they were handling sixty per cent of the amount marketed (De Swardt, 1983: 10). The perverse effects of such a policy are epitomised by the fact that a larger crop actually resulted in a higher domestic price since a levy on domestic prices was used to finance the losses incurred from exporting at a price below cost to get rid of surpluses (Houghton, 1973: 51).

In 1933 a commission of enquiry was appointed to investigate the feasibility of "*one-channel*" "*orderly marketing*" (De Swardt, 1983: 13). The conclusion of this enquiry was, "*No board of control, therefore, however efficiently managed, can hope to attain any degree of success by ignoring the basic factors of price information and, if prices be fixed with due regard to these factors, no board*

*can hope to achieve better results than the competitive system which embraces numerous individual units representing both producers and consumers” (De Swardt, 1983: 14).*

Economists of the time also argued that the financial resources needed by agriculture could be more profitably spent on other industries such as mining, and that benefits to farmers were a burden to the rest of the economy (De Kiewiet, 1957: 259-260). The Maize Board would inevitably have to secure farmer incomes via contrived scarcity rather than increasing the efficiency of the sector via improvements in technology (Houghton, 1973: 59).

The counterargument was that current mineral wealth was transitory, while the land’s fertility would be permanent. Some policy makers consequently argued that agriculture needed to be developed for the long-term sustainability of the South African economy (De Kiewiet, 1957: 248-253). It was also believed that central planning was the only way to *“prevail against isolation and inertia, disease and drought, against ignorance and inefficiency”* (De Kiewiet, 1957: 252).

Given that the government was politically predisposed to help farmers in economic distress, it was thought to be wise to establish permanent and specialised bodies to *“prevent rather than cure”* (De Swardt, 1983: 18). In a complete turnaround from the conclusions of the 1933 commission of enquiry, the 1937 the Marketing Bill was enacted. The role of price discovery and price risk management was thereafter performed by a panel of experts using the tools and information at their disposal to determine prices with the aim of ensuring stability in agriculture.

Use of the *“voorskot”* as a price risk management and price discovery mechanism is essentially the same system that the co-operatives used; the fundamental difference being that farmers could now only sell through the Maize Board (De Swardt, 1983: 11). They could, therefore, make their planting decisions with a worse-case scenario (with respect to prices) in mind. The introduction of disaster relief meant that farmers were also less exposed to the risk of crop failure (Vink and Kirsten, 2000).

The Maize Board’s *“voorskot”* managed to stabilise prices, but at a level much higher than the world price (Houghton, 1973: 60). Surpluses therefore needed to be exported at a loss, meaning that the Maize Board had very similar problems to the co-operatives. One of the fundamental criticisms of the

Marketing Act was that it was merely allowing for an unsustainably high level of income for farmers without making any real improvements<sup>1</sup> (Pringle, 1980: 386). The effect of this was not only inefficiency, but a lack of healthy farming practices, meaning that the inflated price offered by the Maize Board could have severe longer term effects (Houghton, 1973: 61).

While domestic consumption increased steadily after World War II, the Maize Board's task of equating demand and supply by establishing the "right" price involved many difficulties, especially due to climatic variations (Houghton, 1973: 52). So we can see that price control in and of itself is not sufficient to create stability if yield variability is not given a similar amount of attention. Furthermore, we can summarise the last three paragraphs by stating that the Maize Board did not necessarily attempt to set the price at the equilibrium level and any attempt to do so was made difficult by factors out of their control.

From 1987, the Maize Board could no longer rely on government support (Kirsten *et al*, 1994: 35) and the pricing of maize changed to a single-channel pooling scheme where prices are determined in domestic markets as the difference between the Maize Board's operating costs and its sales revenue. This meant that the export loss burden was not so large (Jayne *et al*, 1995: 4). This was the first obvious policy change on the road to complete deregulation. Later, with political change in South Africa and, hence, the need for a rethink of the support that had previously been given to white commercial agricultural and the evolution of the free-market sentiments being pushed by the General Agreement on Tariffs and Trade (GATT), it was decided to deregulate agriculture and leave prices to be dictated by market forces. Single-channel pricing was abolished in 1995 (Vink and Kirsten, 2000: 35).

The looming deregulation of the agricultural sector developed an increasing interest in commodity derivative trading in South Africa and in 1995 the Agricultural Markets Division (AMD) was set-up as an independent part of SAFEX (which had been trading equity derivatives since 1987) (Gravelet-Blondin, 2001: 15). In 2001 SAFEX became part of the Johannesburg Stock Exchange (JSE) and was

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<sup>1</sup> Pringle (1980: 384) notes that there is evidence to suggest that approximately eighty percent of maize farming units were "uneconomical" in the late 1970s.

renamed the Agricultural Products Division (APD) of the JSE Securities Exchange South Africa (SAFEX, 2009: 1).

SAFEX's (and, hence, the APD's) mission is "*to provide the secure and efficient market for trading derivatives in South Africa*" (Gravelet-Blondin, 2001: 20). There is nothing said about helping farmers or price stability or following the fundamentals of the market. To claim that SAFEX is "*not doing what it is supposed to*" would be unfounded since it was established in response to the opportunity created by deregulation and not as a replacement for regulation. This does not mean, however, that SAFEX does not or cannot fulfill some of the Maize Board's former functions.

UNCTAD (2007) claims that among SAFEX's functions are, price risk management and price discovery. They tested these two functions using 22 claims. The ones relevant to our study with respect to price discovery that came out positive are that there is a good alignment of spot and futures markets and prices reflect the fundamentals of the domestic industry. The specific aspects of price discovery where UNCTAD (2007) believe SAFEX has failed are in the avoidance of shortages and gluts, improved prices from intermediaries, the "*squeezing out*" of rent-seeking intermediaries from the supply chain, and reduction in inter- and intra-seasonal price volatility<sup>2</sup>. UNCTAD (2007) could not establish whether or not the market allows farmers to increase income by making cropping decisions based on futures prices. With respect to price risk management, SAFEX was deemed successful as a shield against serious losses when prices fail and in facilitating more effective planning and investment.

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<sup>2</sup> UNCTAD (2007) mention this last point with respect to price discovery although it seems obvious that this is an issue of price risk management.

### III Literature Review

It is well established that a risk averse farmer facing uncertainty about output and/or prices will produce less than he would if these factors were certain or he was risk neutral (Sandmo, 1971). Similarly, Cheung (1970) and Stiglitz (1974) show that a reduction in risk results in an increase in output. Just and Zilberman (1986) show that a downward sloping supply curve is possible under uncertainty. Ozanne (1998) attempts to empirically test the hypothesis of perverse supply raised earlier by Schultz (1960) and developed by Baron (1970). This hypothesis states that the classical production theory result of an increase in output price increasing the output supplied by a firm may not be valid under uncertainty if increases in output prices are accompanied by an increase in variance. Ozanne's (1998) findings do not support perverse supply response, but do indicate the importance of accounting for risk in supply response models.

Just and Zilberman (1986) show that, in the presence of production risk, reducing or managing price risk is not sufficient to account for lower supply due to uncertainty. Newberry and Stiglitz (1979) also argue on two counts that a reduction in price risk is not sufficient to attain income stability. Firstly, given that price and yield disturbances are multiplicative, price stabilisation should be conditioned on yields<sup>3</sup>. Secondly, stabilisation schemes may actually alter mean prices rather than just variances.

Before continuing, we need to establish how risk enters into agents' decisions. Arrow (1971) defines absolute risk aversion as  $-\frac{U''(Y)}{U'(Y)}$ , where Y can be interpreted as uncertain profit. While this applies for any monotonic transformation of the utility function, differences in preferences will result in differences in risk averseness and, as we will continue to argue, differences in behaviour.

Any analysis of risk will, therefore, depend on the utility function assumed. Researchers (Coyle, 1992; Coyle, 1999; Vukina and Holthausen, 1996; Simmons, 2002; Pannell et al, 2008; Woolverton and Skyuta, 2009) have used a mean-variance certainty equivalent of profit with a constant absolute

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<sup>3</sup> In our development of the econometric model, we derive an expression, which demonstrates this point very clearly.

risk aversion (CARA) utility function to analyse the behaviour of farmers under uncertainty. While this approach allows for models from which quite explicit conclusions can be drawn, the CARA assumption is quite restrictive since it only applies to situations with normal distributions and quadratic utility functions (Kroll *et al.* 1984: 47).

Arrow (1971) argues that absolute risk aversion is decreasing in wealth. Not restricting ourselves to CARA then seems to increase realism and allows us to test empirically whether behaviour exhibits CARA, DARA or even increasing absolute risk aversion (IARA). Since non-CARA preferences cause some of the results of neoclassical production theory to break down under uncertainty, we will look at the effects of DARA on both a theoretical model of acreage response and our empirical analysis. Establishing whether farmers exhibit DARA or not will also help us to understand farmers' reactions to risk as well as inform policy aiming to manage risk.

Commodity stabilisation programs (such as the International Commodity Agreements (ICAs)) recognised the role of risk in agriculture and attempted to implement policies and international agreements to mitigate it. While there was extensive debate on this issue, recent (post 1985) consensus has been that these programs were a failure and that market instruments offer more promise as tools to counteract risk (Gilbert, 1995).

This consensus allowed futures markets to emerge as an alternative to commodity price stabilisation schemes. This made analyses of factors determining farmers' decisions to use hedging instruments pertinent.

Mahul (2002) finds that hedging through the use of options is a substitute for crop revenue insurance, but a complement for crop yield insurance. These results are consistent with those of Coble *et al* (2000) who present futures as a hedging instrument. This again brings up the link between production uncertainty and price uncertainty. Accounting for price risk cannot reduce income risk entirely without the help of some form of instrument to reduce production risk.

McKinnon (1967) also emphasises the fact that income variance is dependent on both price and production uncertainty. Moreover, the extent to which price risk and production risk can offset each

other depends on the elasticity of the market demand curve. If the market demand curve is elastic, a decline in production will not increase the price as much as if the demand curve were inelastic. This means that producers operating in a market with an elastic demand curve will be given no reprieve from production risk by a corresponding increase in prices.

A point that McKinnon (1967) makes even more strongly is that commodity stabilisation policies should not focus on spot prices, but rather on long-term futures prices since these allow farmers sufficient security to make planting decisions, while not distorting these decisions. McKinnon's concept would have been applicable to the Maize Board's operations even though he was dealing with global commodity price stability, whereas they were only concerned with South African farmers. The Maize Board's "*voorskot*" meant some stabilisation of spot prices even though it was decided upon prior to planting.

Recent attempts to model the optimal hedging decisions of farmers have been less concerned with commodity price stability. Building on McKinnon's (1967) theoretical model, they attempt to explain why the actual behaviours of farmer deviate from those predicted by their respective models.

Most of these analyses use survey data from interviews with farmers, perhaps due to the influence of behavioural economics' analyses of research validity (Roe and Just, 2009).

Maximising a mean-variance certainty equivalent of profit function, Pannell et al (2008) find that the optimal hedge ratio decreases with increases in transaction costs and basis risk. The optimal hedge also decreases as production fluctuations increase, in line with the intuition given earlier by McKinnon (1967). The basic idea remains that while hedging can reduce price risk, production risk needs to be mitigated in some other way, especially when producers face near perfect competition. For example, if price elasticity is one, then a percentage change in production is exactly balanced by a percentage change in price and, hence, revenue is unchanged. The further elasticity deviates from one, the more extreme the effect of output changes on revenue and *vice versa*.

Pannell *et al* (2008) then use the data collected from their survey to analyse how this optimal decision changes for different levels of risk aversion. Given zero transaction costs, no basis risk and spot price

expectations equal to the futures price, the optimal hedge is 100% of expected output irrespective of risk aversion. They then find that basis risk, transactions costs and production uncertainty have, at best, a moderate effect on hedging decisions. What can have a more dramatic effect, however, are the different expectations between farmers of the future spot price, which Pannell *et al* (2008) find to be quite significant. They conclude from this that futures markets are used by Australian farmers to increase profits (speculate) rather than to reduce risk (hedge).

This demonstrates the importance of accurate price discovery, but also exposes that it is realistically unattainable. Hayek (1945) and, more formally, Grossman and Stiglitz (1989) argue that informational efficiency will never be perfect, which allows for the differences in expected prices and speculative profits to be made. We will look, theoretically and empirically, at how farmers respond to expected prices.

Comparing South African and US maize farmers, Woolverton and Skyuta (2009) observe that farmers in the USA aided by income support programs hedge 20% to 30% less than South African farmers. Importantly, they find that South African farmers make their price risk management decisions prior to planting, whereas US farmers split theirs, making them initially prior to planting and again prior to harvesting. This makes the use of an acreage response model particularly appropriate for an analysis of South African maize farmers

There is a substantial literature, especially from the United States, which looks at determinants of acreage response under uncertainty. Acreage response models are popular due to the fact that the acreage planted is one of the few factors over which farmers have complete control. Actual supply is too dependent on weather conditions and other idiosyncratic factors related to yields, making it unsuitable for the study of farmers' decisions.

One of these models, developed by Chavas and Holt (1990), attempts to close the gap between theoretical and empirical findings using acreage response. Chavas and Holt (1990) set up a theoretical model in which a farming household maximises its expected utility based on adaptive expectations. Money earned to purchase a composite good (from which utility is derived) may come

from non-farm income (or wealth) and from uncertain farming profits, the uncertainty being due to unknown future prices and yields at the time of planting. The paper shows that the optimal acreage decision depends on wealth, expected profits and the variance of profits.

Using a condition from Chavas and Pope (1985), Chavas and Holt (1990) manage to establish that under risk neutrality or, more generally, constant absolute risk aversion (CARA) the optimal acreage decision function is homogenous of degree zero in input and output prices, but that this condition breaks down once any other form of risk aversion is imposed. They also claim that, under risk neutrality, the optimal decision function does not depend on wealth or the variance of income<sup>4</sup>. Hence, if it can be shown that the optimal decision function does depend on either one or both of these factors, the farmer's behaviour deviates from that of risk neutrality. They make no specific mention of decreasing absolute risk aversion (DARA) as part of this discussion, but we can infer that if both wealth and variance affect the optimal decision function, then we have DARA.

To test these theoretical findings Chavas and Holt (1990) take a first-order Taylor approximation of the unknown acreage response function. They then use an expression (similar to the Slutsky equation) to estimate the coefficient of a wealth compensated change in expected profits. They estimate this econometric model using a Seemingly Unrelated Regression (SUR) for corn and soybeans on the basis of which they reject the null hypotheses of risk aversion and CARA for both crops.

Jordaan and Growe (2007) have shown, using a survey of fifty maize farmers in the Valhaarts region, that *less* risk averse and more educated farmers are more likely to adopt the use of forward contracting. Ueckermann *et al* (2008) came to a similar conclusion from their sample of fifty Grain SA registered maize and wheat farmers. Such observations suggest that many farmers perceive the risks associated with using the futures market to be greater than those in farming itself. The idea of subjective uncertainty raised by Simon (1959) is clearly an issue.

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<sup>4</sup> Coyle (1992) shows this more rigorously.

The main downside of these papers is that there is no indication of how farmers use hedging instruments to react to different scenarios in different years and how this affects their actual farming decisions. While they provide valuable information as to the characteristics of the farmer who is willing and able to use hedging instruments, this paper aims to add to their external validity (Roe and Just, 2009) by looking more generally at how farmers have changed their farming decisions over the years, while attempting to take into account provincial heterogeneities.

Wu and Adams (2002: 58) claim that the use of aggregate data is a better forecaster of acreage response than micro-level data, but that micro-level data is better for studying the impact of site specific factors<sup>5</sup>. Given that our data is region-specific and that the inferences we are trying to make are also region-specific, our choice of data type is appropriate and will allow our analysis to complement those of Jordaan and Grove (2007), Ueckermann *et al* (2008) and Woolverton and Skyuta (2009).

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<sup>5</sup> Wu and Adams (2002) focus on environmental factors.

#### IV Theoretical model

We draw on the work of Chavas and Holt (1990) to develop a model that can answer our research questions in the South African historical context. To do so, we allow for farmer heterogeneity as well as for the existence of a futures market for the output.

A farm household's agricultural revenue and cost in any period are given by

$$R = \sum_{i=1}^n p_i Y_i A_i$$

$$C = \sum_{i=1}^n c_i A_i$$

For  $i = 1, \dots, n$  crops where  $p_i$  is the market price per unit of crop  $i$ ,  $Y_i$  the yield of crop  $i$  and  $c_i$  the cost per acre to produce crop  $i$ .  $\mathbf{p} = (p_1, \dots, p_n)$  and  $\mathbf{Y} = (Y_1, \dots, Y_n)$  are unknown at the time of planting, whereas  $\mathbf{c} = (c_1, \dots, c_n)$  is assumed to be known. The household chooses  $\mathbf{A} = (A_1, \dots, A_n)$  at planting time.

In addition to crop sales, the household can also earn (or lose) income by hedging at planting time. This income (loss) is equal to

$$H = \sum_{i=1}^n (f_i - p_i) h_i$$

Where  $\mathbf{f} = (f_1, \dots, f_n)$  is the futures price<sup>6</sup> at planting time for crop  $i$  at harvest time and  $\mathbf{h} = (h_1, \dots, h_n)$  is the amount of contracts per crop entered into when planting. A positive value for  $h_i$  corresponds to holding a short position so we would expect all the  $h_i$  to be positive, but as mentioned in the literature review, it is possible for farmers to hold a long position so we do allow for negative  $h_i$ .

<sup>6</sup> In South Africa, prior to 1996, we can interpret this as the "voorskat". We, therefore, use the term *expected price* and *futures price* interchangeably.

The household attempts to maximise expected utility in a von Neumann-Morgenstern utility function in which utility is gained from consumption of a composite good,  $G$ , subject to a budget constraint, production constraint and hedging constraint<sup>7</sup>.

$$\text{Max}_G EU(G)$$

Subject to

$$w + R - C - H = G$$

$$g(A) = 0$$

$$k(h) = 0$$

$W$  is income from non-agricultural activities or previously held wealth. All variables are in real terms.

The problem can be rewritten as

$$\text{Max}_{A,h} EU \left( w + \sum_{i=1}^n p_i Y_i A_i - \sum_{i=1}^n c_i A_i + \sum_{i=1}^n (f_i - p_i) h_i \right)$$

The first-order conditions are

$$(1) \quad \frac{\partial EU(\cdot)}{\partial A} = E \left( (py - c) \cdot \frac{\partial U}{\partial w} \right) - \lambda \left( \frac{\partial g(A)}{\partial A} \right) = 0$$

$$(2) \quad \frac{\partial EU(\cdot)}{\partial h} = E \left( (f - p) \cdot \frac{\partial U}{\partial w} \right) - \mu \left( \frac{\partial k(h)}{\partial h} \right) = 0$$

$\lambda$  and  $\mu$  are the Lagrange multipliers, which can be interpreted as the marginal utility of an exogenous productivity shock or relaxation of the hedging restrictions, respectively.

Hence, we can define the optimal acreage decision  $A^*$  as a function of wealth,  $w$ , the futures price as well as expected profits and possibly higher moments thereof. We write the optimal acreage function as  $A^*(w, \bar{\pi}, \sigma, f)$ .  $\bar{\pi} = (\bar{\pi}_1, \dots, \bar{\pi}_n)$  with  $\bar{\pi}_i = E(p_i Y_i - c_i)$ , which is the expected<sup>8</sup> profit for crop  $i$

<sup>7</sup> The number of contracts (long or short) a farmer can purchase is restricted by factors such as margin requirements and transaction costs.

<sup>8</sup> This is not the first moment of a probability distribution over profits. It is a scalar that indicates farmers' expectations of profits based on what they expect prices and yields to be and what they know costs to be. This differs to Chavas and Holt (1990), who assume adaptive expectations.

based on expected prices and expected yields.  $\sigma = (\sigma_1, \dots, \sigma_n)$ <sup>9</sup> is the variance-covariance matrix<sup>10</sup> of profits.  $f$  is the expected price and  $w$  is wealth.

$A^*(w, \bar{p}, \sigma, f)$  is homogenous of degree zero in  $(w, p, c, f)$  for all risk preferences expressed by  $U(\cdot)$ . However, as is shown by Pope (1988: 120), homogeneity of degree zero in output and input prices only is not assured and will depend on risk preferences. This is due to the wealth term, since, *ceteris paribus*, an equal increase in input and output prices (leaving profit unchanged) may affect the optimal choice of acreage. This means that the classical production theory result of optimal decisions depending only on input output price ratios does not apply for all preferences (Chavas and Holt, 1990: 530).

Recall the three hypotheses this paper investigates. The first corresponds to risk aversion and DARA; if farmers' decisions are affected by the variance of profits, we can say that they are risk averse and, furthermore, according to Chavas and Holt (1990) positive wealth effects imply DARA<sup>11</sup>. The second relates to price discovery, which can be analysed by looking at how the expected price affects optimal decisions. Finally is that of price risk management, which can be analysed by looking at the role the expected price plays in reducing the effect of variance on optimal decisions. While we need to wait for the empirical model to be able to test our specific hypotheses, the model we have set up and are about to elaborate on will give us an indication of what results to expect, while also providing theoretical support for them.

To the end of establishing homogeneity conditions of the optimal acreage response function under uncertainty, Chavas and Holt (1990) combine their first-order conditions with condition (3) below derived by Chavas and Pope (1985) from the nullity conditions of the Lagrangian, which holds for all risk preferences.

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<sup>9</sup> Chavas and Holt (1990) use  $\sigma$  to denote the variance instead of  $\sigma^2$  as is usually done. We follow their notation.

<sup>10</sup> By only including the variance of profits and not any higher moments, we have implicitly assumed that the variance of profits is normally distributed since the normal distribution is fully characterized by its first two moments.

<sup>11</sup> This, however, is not always the case. Positive wealth effects are necessary, but not sufficient for DARA.

$$(3) \quad \frac{\partial A^*}{\partial \bar{\pi}} \left( \frac{\partial g(A)}{\partial A} \right) - \frac{\partial A^*}{\partial w} \left( \frac{\partial g(A)}{\partial A} \right) A = \mathbf{0}$$

This is essentially a special case of the Slutsky equation for factor demand. The first term is the substitution effect due to a change in expected profits, while the second is an income effect.

Substituting in for  $\left( \frac{\partial g(A)}{\partial A} \right)$  and  $E \left( \frac{\partial U}{\partial w} \right)$  from (1) and (2), respectively we obtain the following expression<sup>12</sup>

$$(4) \quad \frac{\partial A^*}{\partial \bar{\pi}} (\bar{\pi} - \Gamma E(\mathbf{f} - \mathbf{p})) - \frac{\partial A^*}{\partial w} (\bar{\pi} - \Gamma E(\mathbf{f} - \mathbf{p})) A = \mathbf{0}$$

where

$$\Gamma = \frac{\text{Cov} \left( (\mathbf{p}\mathbf{y} - \mathbf{c}), \frac{\partial U}{\partial w} \right)}{\text{Cov} \left( (\mathbf{f} - \mathbf{p}), \frac{\partial U}{\partial w} \right) - \mu \left( \frac{\partial k(\mathbf{h})}{\partial \mathbf{h}} \right)}$$

for  $\text{Cov} \left( (\mathbf{f} - \mathbf{p}), \frac{\partial U}{\partial w} \right) \neq \mu \left( \frac{\partial k(\mathbf{h})}{\partial \mathbf{h}} \right)$

Assume diminishing marginal utility of wealth (i.e. that  $U'(\cdot) > 0$  and  $U''(\cdot) < 0$ ). For constant absolute risk aversion (CARA) and, more specifically, risk neutrality, we have that  $\Gamma = 0$  and

$\frac{\partial A^*}{\partial w} = 0$  (Chavas and Holt, 1990: 531), reducing (4) to

$$(5) \quad \frac{\partial A^*}{\partial \bar{\pi}} \bar{\pi} = 0$$

This demonstrates that under CARA preferences (assuming no other wealth effects) the acreage response function is homogenous of degree zero in input and output prices. That is if,  $\mathbf{p}$  and  $\mathbf{c}$  are increased by the same factor, optimal acreage will not change. If, however, we allow for non-CARA preferences this need not be the case.

If  $E(\mathbf{f} - \mathbf{p}) = \mathbf{0}$ , then risk aversion no longer plays a role in optimal decisions since  $\Gamma$  (which is where risk aversion is accounted for via the covariance between marginal utility and profits) will then have no impact on the optimal decision .

<sup>12</sup> We also require the fact that  $E(XY) = \text{Cov}(X, Y) + E(X)E(Y)$ .

However,  $\frac{\partial A^*}{\partial w} > 0$ , which Chavas and Holt (1990) interpret as DARA may have an effect. If risk aversion is not affecting optimal decisions then it is impossible for the farmer to have DARA preferences. Therefore, these positive wealth effects must certainly be due to a factor distinct from DARA. Nevertheless, we can say that an efficient futures market is a sufficient price risk management tool regardless of individual preferences.

If we assume that the expectation of future spot prices depends on the individual's information set, we have  $E[\mathbf{p}|\mathbf{I}_I]$ . This means that some farmers may believe the futures price is an underestimate and others may believe it is an overestimate (i.e.  $E[\mathbf{p}|\mathbf{I}_I] \neq \mathbf{f}$ ). This will affect their decision to hedge or speculate, either through the futures market itself or by planting more or planting less.

The “magnitude” of this decision will depend on gamma (i.e. risk preferences). Diminishing marginal utility of wealth means that  $Cov\left(\mathbf{p}\mathbf{y} - \mathbf{c}, \frac{\partial U}{\partial w}\right)$  and  $Cov\left(\mathbf{f} - \mathbf{p}, \frac{\partial U}{\partial w}\right)$  are negative. If farmers hold a short position,  $\mu\left(\frac{\partial k(\mathbf{h})}{\partial \mathbf{h}}\right)$  will be positive<sup>13</sup>, making  $\Gamma > 0$ . If, however, farmers speculate by taking a long position and  $\mu\left(\frac{\partial k(\mathbf{h})}{\partial \mathbf{h}}\right)$  becomes sufficiently negative then it is possible that  $\Gamma > 0$ . For farmers to take a long position, their expectations of the future spot price would need to be higher than the futures price ( $E[\mathbf{p}|\mathbf{I}_I] > \mathbf{f}$ ). This means that  $E(\mathbf{f} - \mathbf{p})$  and  $\Gamma$  will always have opposite signs and, hence, the  $\Gamma E(\mathbf{f} - \mathbf{p})$  term will always be negative. The significance of this result is that we only need two conditions to hold for an increase in acreage due to an increase in expected profits to be less than under full certainty: firstly, we require farmers to be risk averse and secondly, we need their individual expectation of future spot prices to be different from that represented by the futures price. Hence, we only need for one of these conditions not to hold for the acreage response to be the same as under full certainty. The implications of this result for our second and third question will be discussed below.

These results can give us some guidance for interpreting the results from our econometric estimation. With respect to the first question, we have found that, for a given level of expected profits, a risk

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<sup>13</sup> An increase in  $\mathbf{h}$  corresponds to the farmer holding more (fewer) short-position (long-position) contracts.

averse farmer will plant less than a risk neutral farmer. Furthermore, a farmer with DARA preferences (or any other positive wealth effects) will plant less. Therefore, if we find that variance has a negative effect on acreage, farmers must be risk averse. Furthermore, if at the same time, wealth has a positive effect on planting, farmers exhibit DARA (or other positive wealth effects).

We can say that the further a risk averse farmer's expectations are from the expected price, the less they will plant, meaning that an increase in the expected price may not increase optimal acreage if the farmer's expectation is higher. This would mean that farmers should respond more positively to an increase in the "voorskot" than an increase in the futures price since it is more closely aligned to the future spot price. Also, this means that, if we were to find that farmers planted less after an increase in the expected price that it was due to fact that their individual expectation of the price is higher. However, this result could also be indicating perverse supply response. This means that inferences from the results regarding price discovery (our second question) will always have an element of conjecture.

Regarding price risk management (our third question), we can say that an efficient futures market is sufficient to allow farmers to mitigate risk completely if farmers can enter into a futures contract to counter their long or short planting position.

In the next section, we operationalise these relationships in a model that can be taken to the data.

## V Econometric Model

We take a Taylor first-order approximation of the optimal acreage function  $A^*(w, \bar{\pi}, \sigma, f)$ , which gives

$$(6) \quad A_{ilt} = a_i + \frac{\partial A_{il}}{\partial w} w_{l,t-1} + \sum_{j=1}^n \frac{\partial A_{il}}{\partial \bar{\pi}_{jl}} \bar{\pi}_{jlt} + \sum_{k \geq j}^n \sum_j \frac{\partial A_{il}}{\partial \sigma_{jlk}} \sigma_{jlk} + \sum_{j=1}^n \frac{\partial A_{il}}{\partial f_j} f_{jlt}$$

Where  $A_{ilt}$  is the acreage planted to crop  $i$  by individual  $l$  during year  $t$

This extends equation (9) in Chavas and Holt (1990) to include a futures price and allow for the fact that acreage decisions are allowed to vary between individuals.

Using the standard production theory result that  $\frac{\partial A^c}{\partial \bar{\pi}} = \frac{\partial A^*}{\partial \bar{\pi}} - \frac{\partial A^*}{\partial w} \cdot A^*$  (Mas-Collel *et al*, 1995: 71),

which applies for all risk preferences and letting  $\beta_{ilj} = \frac{\partial A^c}{\partial \bar{\pi}}$ , where  $A^c$  is the wealth compensated acreage decision, (6) becomes

$$(7) \quad A_{ilt} = a_i + \alpha_{il}(w_{l,t-1} + \sum_{j=1}^n A_{jl} \bar{\pi}_{jlt}) + \sum_{j=1}^n \beta_{ilj} \bar{\pi}_{jlt} + \sum_{k \geq j}^n \sum_j \frac{\partial A_{il}}{\partial \sigma_{jlk}} \sigma_{jlk} + \sum_{j=1}^n \frac{\partial A_{il}}{\partial f_j} f_{jlt}$$

Futures prices have no  $l$  subscript due to the fact that available futures prices are the same for all farmers (ignoring location differentials). The expectation and variance of profits, however, depend on yields and costs, which do differ between farmers.

Equation (7) applies to a situation where farmers have the choice of planting several crops. We restrict ourselves to a single crop, which means that the acreage response for a particular crop is not affected by yields, prices and variations of other crops. This gives us a special case of equation (7).

$$(8) \quad A_{lt} = a_l + \alpha_l(w_{l,t-1} + A_l \bar{\pi}_{lt}) + \beta_l \bar{\pi}_{lt} + \frac{\partial A_l}{\partial \sigma_l} \sigma_{lt} + \frac{\partial A_l}{\partial f} f_t$$

To be able to test the respective effects of yield and price variance, the  $\sigma_{lt}$  term can be decomposed into a variance in prices  $\sigma_t^p$  and a variance in yields,  $\sigma_{lt}^y$ . There is no straight-forward expression for the variance of the product of random variables, but it is shown in the Appendix that<sup>14</sup>

$$(9) \quad \sigma_{lt} = \sigma_t^p E(y_t)^2 + \sigma_{lt}^y E(p)^2$$

Intuitively, this tells us that a variation in yield has a lower effect on profits for a lower mean price. As an extreme example, a variation in yield will have no effect on profits if the price is zero and *vice versa*. This means that it is difficult to decipher whether a rise in the variance of profits is due to a higher variance in yield or price or merely a greater impact of the same variation due to higher expected yield or price. This demonstrates the point made several times during the literature review; accounting for price instability is not sufficient to secure income stability.

The empirical issue, though, is entering this expression into equation (8) so that we may see the relative impacts of yield and price variation. From the following we will see the importance of the interpretation of the coefficients that the Taylor expansion allows. We focus on the  $\frac{\partial A_l}{\partial \sigma_l} \sigma_{lt}$  coefficient from equation (8). In the Appendix we show that

$$(9) \quad \frac{\partial A_l}{\partial \sigma_l} \sigma_{lt} = \frac{\partial A_l}{\partial \sigma^p} \sigma_t^p + \frac{\partial A_l}{\partial \sigma_l^y} \sigma_{lt}^y$$

Substituting this into equation (8) gives us the following

$$(10) \quad A_{lt} = a_i + \alpha_l (w_{l,t-1} + A_l \bar{\pi}_{lt}) + \beta_l \bar{\pi}_{lt} + \frac{\partial A_l}{\partial \sigma^p} \sigma_t^p + \frac{\partial A_l}{\partial \sigma_l^y} \sigma_{lt}^y + \frac{\partial A_l}{\partial f} f_t$$

This equation provides a basis for us to answer our three questions empirically.

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<sup>14</sup> This assumes independence of yields and prices since the yields of one farmer will not influence the price can obviously not affect yields.

## VI Data

We create a panel over four regions of South Africa for the period 1971-2008<sup>13</sup> using aggregate data. The first region is composed of the Western Cape, Eastern Cape and Northern Cape (formerly known as the Cape Province), the second is the Free State (formerly known as the Orange Free State), the third is Kwazulu Natal (formerly known as Natal) and the fourth is composed of Gauteng, North West, Limpopo and Mpumalanga (formerly known as the Transvaal).

Data for provincial areas were obtained from SAGIS. Figure 1 shows that the downward trend in area planted to maize for the two major growing regions has shown a similar pattern, while Region 1 has shown an almost opposite trend.

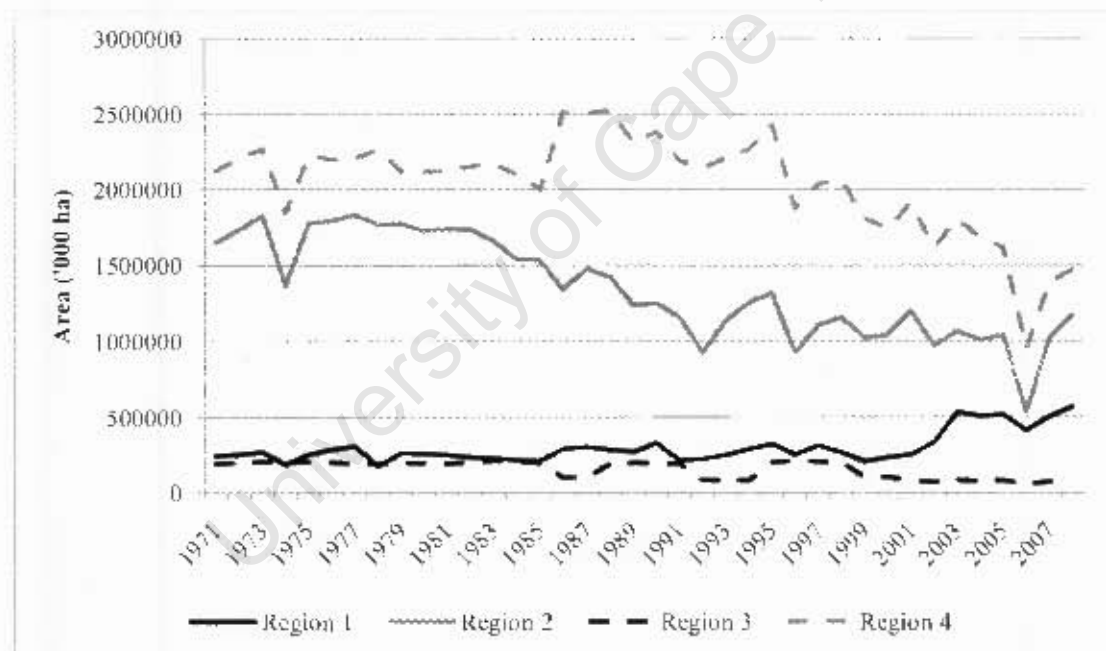


Figure 1: Areas Planted to Maize (Source: SAGIS)

We define wealth as the average size of a maize farm multiplied by the value of this land, for which data is obtained from various agricultural censuses. Censuses are not published regularly so missing figures were computed as the average of the previous year and next year for which data is available. We would not expect large fluctuations in wealth and this method allows wealth to change smoothly.

<sup>13</sup> Throughout, a year written as 1971 will refer to the 1970/1971 season.

To get this into Rand terms and to distinguish between the values of a hectare of land in different regions, we multiply this average farm size by the gross income of maize production in that region. Table 1 shows the mean wealth over the sample period for the four regions. It is clear to see that the Cape provinces and Kwazulu Natal are far less wealthy than the other regions. This is as expected since most commercial maize farming occurs in regions 2 and 4, while maize farmers in regions 1 and 3 are likely to be small-scale farmers. This indicates that the differences in wealth between regions are more likely to affect our results than changes in wealth over time.

Region	Mean wealth (R '000000)
1	2.16
2	392
3	9.16
4	93.2

*Table 1: Mean Wealth per Region (Source: Own calculations from various issues of the Census of Commercial Agriculture)*

Producer prices for the entire sample are obtained from the 2009 Abstract of Agricultural Statistics. Expected prices or "voorskot" prices for the period 1971 to 1996 are also obtained from this source. From 1997 onwards the expected price is the average of the July (harvest time) futures price during October, November and December (planting time), data for which is obtained from SAFEX. This method of calculating the expected price is used by others including Choi and Helmberger (1993). All price data is assumed the same for all regions. All prices are the average of the yellow maize and white maize prices. The effect of the expected price changing from the "voorskot" to the futures price is clear to see from Figure 2. While the mean level of this expected price appears similar pre- and post-1996, the interseasonal variance seems greater. Figure 2 also shows the fundamental difference between the "voorskot" and the futures price. Pre-1996 the producer price is always equal to or greater than the expected price, whereas post-1996 this is seldom the case.

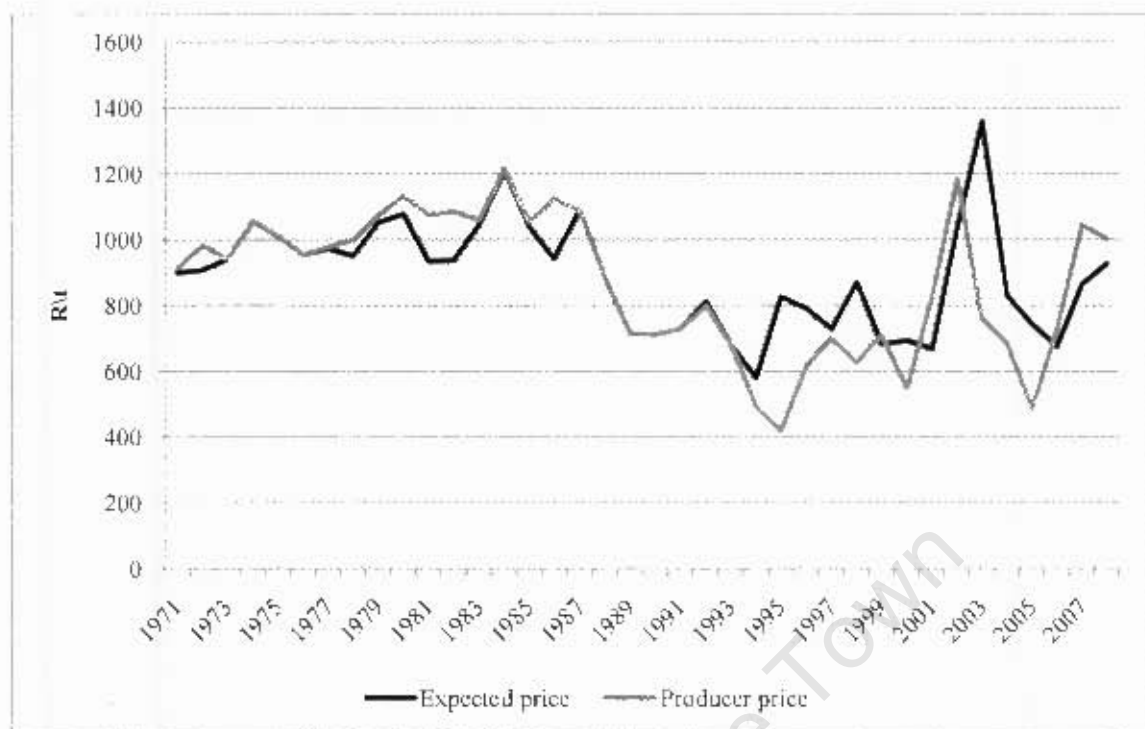


Figure 2: Expected Price and Producer Price of Maize (Sources: Abstract of Agricultural Statistics and SAFEX)

The variance of prices is then calculated as follows

$$\sigma_t^2 = \sum_{j=1}^3 \omega_j [p_{i,t-j} - E_{t-j-1}(p_{i,t-j})]^2$$

Where the  $\omega_j$  are 0.5, 0.33 and 0.17 respectively<sup>16</sup>.  $p_{i,t-j}$  refers to the gross producer price, whereas  $E_{t-j-1}(p_{i,t-j})$  refers to the expected price as defined above. It seems intuitive that farmers would react more to recent deviations from the expected price and these are the weights used by Chavas and Holt (1991) and others<sup>17</sup>. While the weights are *ad hoc*, they mention trying several other combinations, which do not change the results.

The expected value and variance of yields are obtained by running an OLS regression of yields on time for each region over the period 1971 to 2008. The linear trend is then used as the expected yield, while the lagged residuals are used as a measure of the variance, as do (Chavas and Holt, 1990).

<sup>16</sup> These are the weights used by Chavas and Holt (1990: 533), who claim that their results were robust to several different weight combinations.

<sup>17</sup> While this definition of variance does have an element of adaptive expectations to it, it is not technically so due to the fact that the expected price is not defined according to adaptive expectations.

Figure 3 shows that there is no obvious relationship between yields in Regions 2 and 3, which illustrates the basic pattern for all regions.

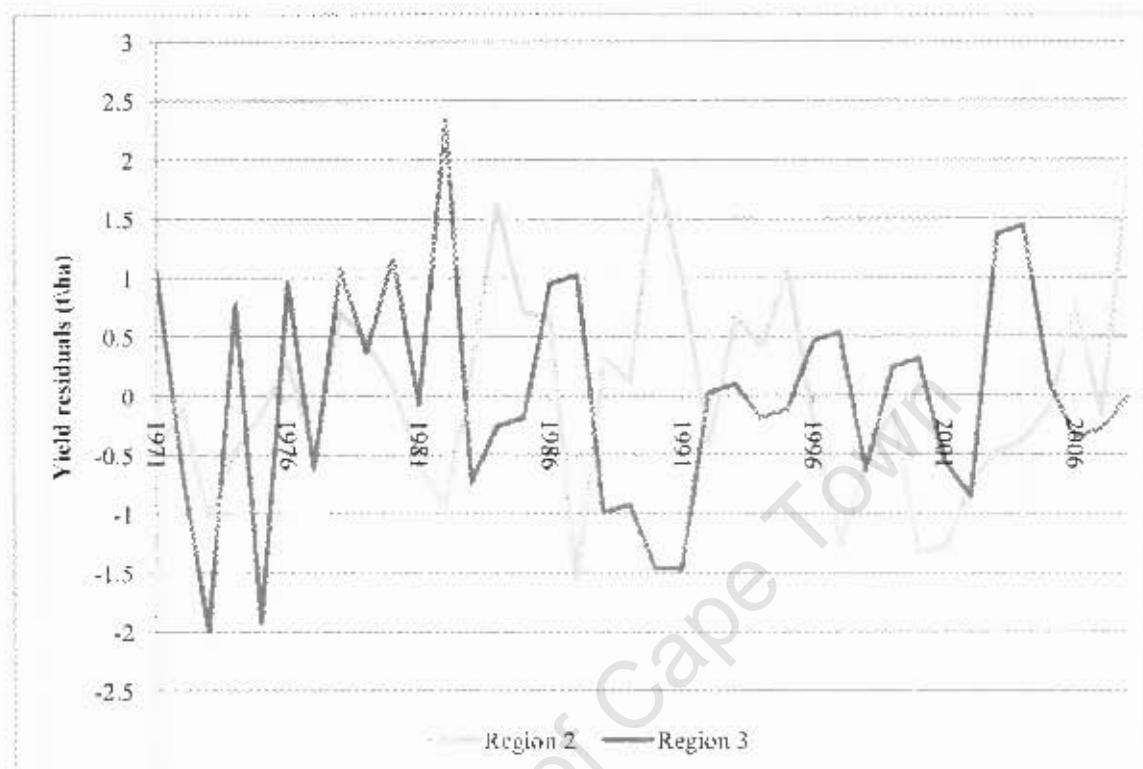


Figure 3: Yield Residuals (Source: Own calculations using data from the Abstract of Agricultural Statistics 2009)

No per acre cost data is available for South African provinces or South Africa as a whole. However, an index of input prices<sup>18</sup> for South Africa is available in the Abstract of Agricultural Statistics 2009. To be able to use this index as a measure of cost per acre we need a Rand figure for cost per acre for one year to anchor the index. We do this by looking at Gross income from the production of maize in each province, which is taken from the 2002 Agricultural Census. We subtract this gross income from revenues (gross producer prices multiplied by production) and divide by the area planted to maize. This is then the cost per acre for 2002, which we set as a base and use the input index to get a proxy for costs per acre per province for the sample period. While this measure of costs per acre is clearly not perfect, it gives a good indication of the relative costs over the sample period.

<sup>18</sup> The input price index includes animal feed, which we exclude and then weight up fertilizer and seed costs to make up the difference.

Once all calculations have been done, we are left with a panel where  $N=4$  and  $T=35$ . The next section discusses econometric issues associated with a dataset of this nature.

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## VII Panel Data Techniques

Our panel is relatively long ( $T=35$ ,  $N=4$ ) so its characteristics are different to microeconomic datasets, where the  $N$  dimension is much larger or many macroeconomic datasets (like the Penn World Tables), where the dimensions are roughly equal in magnitude. This is important due to the fact that many panel data techniques are unsuitable for a panel of this nature.

We start our econometric analysis with the standard fixed effects regression

$$y_{it} = \alpha + X_{it}\beta_1 + Q_t\beta_3 + u_i + v_{it}$$

While the  $u_i$  term allows us to account for unobservable province-specific effects, which may otherwise cause heteroscedasticity, the  $v_{it}$  may violate the assumption of no serial correlation due to serially correlated omitted variables or transitory variables whose effects last more than one period<sup>19</sup> (Hsiao, 2003: 57). This is an issue in long panels, so we look at ways to test for serial correlation and account for it if necessary.

The simplest and most intuitive test for serial correlation is described by Wooldridge (2002: 275). He suggests finding the residuals from the fixed effects regression and running pooled OLS of these residuals on their lagged value. This entails running the following regression

$$\hat{v}_{it} = \rho\hat{v}_{i,t-1} + \varepsilon_{it}$$

If  $\rho$  is deemed to be significant (using a standard t-test with robust standard errors), serial correlation may be present. Wooldridge (2002: 275) states that this is not an optimal test for AR(1), but that it can be good enough to indicate a problem.

We can, therefore, also test to see whether the residuals for each panel have symptoms of autocorrelation. We can do this by looking at the correlogram and Q-statistics.

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<sup>19</sup> A possible example is a change in weather conditions lasting more than one period or factors related to the business cycle.

If we do find evidence of serial correlation, Wooldridge (2002: 275-276) suggests using a robust asymptotic variance matrix, but reminds us that its use is only valid for T small relative to N so it is not appropriate here.

An alternative is to include one or more lags of the dependent variable as a regressor as per Nerlove (1979). If serial correlation is being caused due to the fact that the dependent variable is an AR(1) this should remove the problem. This approach may lead to an inconsistent estimator due to Nickell bias (Nickell, 1981), but this becomes negligible for panel datasets where T is relatively large<sup>20</sup> (Arellano, 2003: 86).

Once this technique has been attempted, we can use the same methods described above to test whether serial correlation has been cured. If we can say, with some degree of confidence, that it has then we can move on to draw inferences without the overconfidence that we may have had if we had ignored serial correlation. If not, we may need to include another lag to better account for serial correlation.

Another approach is to use an autoregressive fixed effects model, which makes adjustments for potential autocorrelations. For a known  $\rho$  we can make the following transformation

$$y_{it} - \rho y_{i,t-1} = \alpha(1 - \rho) + (X_{it} - \rho X_{i,t-1})\beta_1 + (Q_t - \rho Q_{t-1})\beta_3 + u_i(1 - \rho) + \varepsilon_{it}$$

Notice that the residuals for this model are serially uncorrelated. Equivalently, Baltagi and Li (1991) claim that pre-multiplying a model with AR(1) errors by a matrix C can transform it into one with serially uncorrelated errors where

$$C = \begin{pmatrix} (1 - \rho^2)^{1/2} & 0 & 0 \dots & 0 & 0 \\ -\rho & 1 & 0 \dots & 0 & 0 \\ 0 & -\rho & 1 \dots & 0 & 0 \\ 0 & 0 & -\rho \ddots & \vdots & \vdots \\ \vdots & \vdots & \vdots \ddots & 1 & 0 \\ 0 & 0 & 0 \dots & -\rho & 1 \end{pmatrix}$$

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<sup>20</sup> While the effects may still be significant for T=15, T=20 is sufficiently large (Arellano, 2003: 87).

Using the inverse of the covariance matrix of the transformed errors and initial estimates for  $\rho^{21}$ , the model can be estimated using Generalised Least Squares (GLS).

We now apply these techniques to equation (10) and variations thereof.

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<sup>21</sup> The `-xtregar-` command in Stata gives many options for estimating this autocorrelation. We will use the default, which makes use of the Durbin-Watson statistic.

## VIII Results and Discussion

Table 2 shows the results of estimations conducted using a standard fixed effects regression as well as two models which attempt to account for serially correlated errors; one includes a lag of the dependent variable and the other is autoregressive fixed effects regression as explained above. The results are in columns (1)-(3). Columns (4)-(7) present additional specifications using the two models accounting for serial correlation.

The t-statistics for  $\rho$  in the Wooldridge (2002) test developed above are shown in Table 2. This figure for regression (1) indicates that there may be serial correlation. Once the lag is included in regressions (2), (4) and (6) we see that we cannot reject the null hypothesis of no serial correlation. Table 4 in the Appendix shows the p-values for the Q-statistic (Portmanteau test statistic for white noise). We can conclude that the Q-statistic is significant for all panels for regression (1) and insignificant in all panels except panel 1 for regressions (2), (4) and (6).

Of course these tests are uninformative for the autoregressive fixed effects regression since it, by design, assumes serially correlated errors. However, the Baltagi-Wu (1999) LBI statistic reported in Table 2 indicates the validity of using this regression technique. While critical statistics for this test are hard to find (Baltagi and Wu, 1999: 822), our LBI statistics are all close to zero indicating positive serial correlation in a similar manner to the Durbin-Watson statistic.

We conclude that including the lag of the dependent variable or using an autoregressive fixed effects regression solve the problem of serial correlation satisfactorily.

This allows us to move on to interpret the results from the seven regressions in Table 2.

**Table 2**

	(1) $A_t$	(2) $A_t$	(3) $A_t$
$A_{t-1}$		0.661*** (0.0483)	
$w_{t-1} + A\bar{\pi}_t$	3.20e-06*** (5.21e-07)	2.36e-06*** (3.40e-07)	2.95e-06*** (2.79e-07)
$\bar{\pi}_t$	-105.2*** (37.64)	-13.67 (25.07)	-65.41 (43.60)
$\sigma_t^p$	-1.152*** (0.436)	-0.790*** (0.281)	-0.269 (0.302)
$\sigma_t^y$	-53,333** (26,794)	-39,602** (17,232)	-22,352* (12,061)
$f_t$	174.4 (111.5)	30.15 (72.38)	155.4 (116.6)
$a$	355,294*** (116,241)	5,389 (78,877)	369,458*** (20,772)
F for no FE	533.7***	24.12***	35.41***
Serial correlation statistic <sup>‡</sup>	0.859***	0.0191	0.526 <sup>†</sup>
F for variances and wealth jointly equal to zero	18.67083***	22.97359***	41.43683***
F for variances jointly equal to zero	7.191835***	8.618223***	2.434558*
F for equality of variances	3.961746**	5.28133**	3.434509*

Standard errors in parentheses

\*\*\* p<0.01, \*\* p<0.05, \* p<0.1

<sup>‡</sup> Wooldridge (2002)  $\rho$  values in columns (1),(2),(4) and (6); Baltagi-Wu (1999) LBI statistic in columns (3),(5),(7)

<sup>†</sup> No critical values available, but a value close to zero indicates positive serial correlation.

Table 2 (continued)

	(4) $A_t$	(5) $A_t$	(6) $A_t$	(7) $A_t$
$A_{t-1}$	0.643*** (0.0546)		0.652*** (0.0531)	
$w_{t-1} + A\bar{\pi}_t$	2.40e-06*** (3.53e-07)	2.86e-06*** (2.80e-07)	2.37e-06*** (3.46e-07)	2.89e-06*** (2.80e-07)
$\bar{\pi}_t$	14.74 (34.70)	-29.65 (44.97)	10.34 (30.66)	-48.38 (43.51)
$\sigma_t^p$	-1.522* (0.855)	-1.281* (0.682)	-1.748** (0.799)	-1.509** (0.611)
$\sigma_t^y$	-35,501** (17,525)	-17,997 (12,526)	-37,152** (17,333)	-21,599* (12,418)
$f_t$	-53.61 (124.7)	115.0 (138.0)	33.76 (72.30)	234.9* (121.1)
$f \cdot D97$	61.26 (166.0)	11.03 (142.7)	-53.06 (44.35)	-131.3* (72.65)
$\sigma_t^p \cdot D97$	1.109 (0.906)	1.380* (0.775)	1.240 (0.869)	1.438** (0.638)
$D97$	-73,154 (131,305)	-72,205 (141,759)		
$t$	-2,212 (2,941)	-12,498* (7,194)		
$a$	158,944 (163,943)	792,466*** (41,258)	40,530 (84,853)	382,551*** (22,062)
F for no FE	21.66***	47.07***	21.94***	43.17***
Serial correlation statistic <sup>†</sup>	0.119	0.589 <sup>†</sup>	0.0418	0.550 <sup>†</sup>
F for variances and wealth jointly equal to zero	21.05963***	40.38383***	21.89452***	43.41362***
F for variances jointly equal to zero	4.264101**	3.171624**	5.828477***	5.288253***
F for equality of variances	4.103206**	2.06391	4.593795**	3.024629*
F for $\sigma_t^p + \sigma_t^p \cdot D97$ $= 0$	1.256328	0.07236	2.158951	0.047912

Standard errors in parentheses

\*\*\* p<0.01, \*\* p<0.05, \* p<0.1

<sup>†</sup> Wooldridge (2002)  $\rho$  values in columns (1),(2),(4) and (6); Baltagi-Wu (1999) LBI statistic in columns (3),(5),(7)

<sup>†</sup> No critical values available, but a value close to zero indicates positive serial correlation.

Regression (1) is an estimate of equation (10). Given the presence of serial correlation in this regression we ignore it. Regression (2) and (3) remove serial correlation using the two techniques described. Regressions (4) and (5) include a dummy variable for 1997<sup>22</sup> indicating the withdrawal of the Maize Board, a time trend as well as interactions between the dummy and expected prices and the dummy and price variance to allow us to test for changes in the price discovery and price risk management functions (questions two and three). These regressions have few significant t-statistics yet high  $R^2$  values, which is often an indication of multicollinearity. To mitigate this, we drop the time trend as well as the 1997 dummy, leaving us with regressions (6) and (7). While we do refer to the other regressions in the analysis to follow, we primarily consider regressions (6) and (7).

The fixed effects regressions all have highly significant F-stats for the presence of panel heterogeneity and, hence, our use of a fixed effects regression is justified<sup>23</sup>. We have now accounted for region specific factors, which are difficult to measure explicitly. The most obvious of these factors would be the differences in growing conditions between the regions.

All coefficients have the likely signs in all regressions, except expected profits and expected prices, which are mostly insignificant. This indicates the possibility of perverse supply response mentioned in the literature review<sup>24</sup>.

While both yield and price variances are mostly significant, we can see that the magnitude of yield variances is higher than that of price variances. To verify that this is not just an illusion of scale we test for the equality of the respective coefficients. The F-stats are reported in Table 2 and are significant at the 5% level for regression (7) and at the 10% level for regression (6). This indicates

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<sup>22</sup> While the Maize Board was withdrawn in 1996, the first SAFEX determined expected price was for the 1996/1997 season.

<sup>23</sup> A Random Effects model yielded a rho value of zero meaning that it is unsuitable for our dataset.

<sup>24</sup> Our calculation of costs may be also influence our results with respect to expected profits. Although logically sound, the index used to create a time series for the different panels was a national one, which also did not take into account availability and liquidity issues.

that farmers' decisions are more responsive to yield risk than price risk; a result we would not have been able to see without distinguishing between the two variances<sup>25</sup>.

We can now begin to attempt to answer the three questions established earlier. According to Chavas and Holt (1990) testing for risk aversion is equivalent to testing the joint linear hypothesis that the coefficient on the wealth term as well as on the variance terms are zero<sup>26</sup> versus the alternative that one of these coefficients is different from zero<sup>27</sup>. If we can reject risk neutrality, Chavas and Holt (1990) claim that testing the null hypothesis of the wealth term coefficient equal to zero is equivalent to testing for CARA. The F-stats for the first test for all seven regressions are highly significant as can be seen in Table 2, while the wealth term is also significantly positive, meaning that, if we were to use Chavas and Holt's (1990) approach we would conclude that South African maize farmers exhibit DARA preferences.

We argue that this sequence of tests is somewhat flawed. It is possible to reject the null hypotheses due to only wealth being significant, which does not necessarily imply DARA. For example, we know that commercial maize farming has substantial economies of scale. Since the way we have calculated wealth takes into account the size of the average maize farm, this term may be informing us of economies of scale rather than DARA.

To ensure that we are not just capturing these effects, it makes sense to test the joint significance of the variance terms only to test for risk aversion. If we can reject risk neutrality in favour of risk aversion then we can test the significance of the wealth term to test for CARA. While we can still not be absolutely sure that a rejection of the null hypothesis of the wealth term coefficient equal to zero implies DARA, it is at least possible if we have already rejected risk neutrality. However, if we cannot reject this null hypothesis after rejecting that of risk neutrality we can comfortably conclude in favour of CARA.

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<sup>25</sup> Perhaps this is technically incorrect due to the fact that the test has two-sided alternative, but take the liberty nonetheless.

<sup>26</sup> i.e.  $H_0: \alpha_l = \frac{\partial A_l}{\partial \sigma^p} = \frac{\partial A_l}{\partial \sigma^y} = 0$

<sup>27</sup> They do not explicitly mention this alternative, but it is implicit for all joint hypotheses. Logically, to prove that  $(a \in B \wedge b \in B)$ , we only need prove that  $(a \notin A) \vee (b \notin B)$ .

Nevertheless, the policy implications of finding positive wealth effects should not depend on what we decide to call them; farmers will respond positively to an increase in wealth no matter what we decide to interpret this term as. Table 3 summarises our possible conclusions for different results of our sequence of tests. Our findings correspond to the top-left cell.

Table 2 also shows the F-stats for the null hypothesis that the variance terms are jointly equal to zero. These F-stats are significant at at least the 5% per cent level for all regressions except for regression (3) where it is only significant at the 10% level. Given that the coefficients on these terms are negative, we can conclude that farmers are risk averse. Given, significantly negative wealth terms, we can also conclude that farmers exhibit DARA preferences, keeping in mind our earlier caveat.

Table 3

$H_0$ : Wealth term insignificant

		Reject (positive coefficient)	Do not reject
$H_0$ : Variances jointly insignificant	Reject (negative coefficient)	<b>Risk averse and DARA and/or non-DARA wealth effects</b>	Risk averse and CARA
	Do not reject	Risk neutral and significant non-DARA wealth effects	Risk neutral

Having addressed our first question, we can now look at how farmers' responses to price discovery (our second question) and price risk management (our third question) have changed since the Maize Board's withdrawal. We have already established that it is difficult to conclude that farmers respond significantly to expected prices, but to see how this has changed once the Maize Board was withdrawn (and the expected price changed from the "voorskot" to the futures price) we need to look at the  $f_t \cdot D97$  term.

The negative coefficient on the  $f_t \cdot D97$  term in regressions (6) and (7) indicates that the expected price derived from the futures price is not as effective a price discovery mechanism as was the "voorskot". However, it is hard to reject the null hypothesis that farmers responded equally to the "voorskot" as they did to the futures price (at best, we can only do so at 10% significance in column (7)). Also note that in regression (6), the  $f_t \cdot D97$  term is greater in magnitude than the  $f_t$  term

indicating a negative response to expected prices post-1996. The caution shown when dealing with price discovery is, therefore, warranted; there are so many complicating factors that it is difficult to make inferences based on the expected price. Our conclusion with respect to price discovery, therefore, is that farmers show little evidence of farmers responding positively to expected prices and that there is little evidence to suggest this has changed since the withdrawal of the Maize Board.

We saw from Figure 2 in the Data section that price risk has increased post-1996. From our econometrics, the interaction term  $\sigma_t^p \cdot D97$  shows some evidence that farmers have changed their reaction to price risk since the withdrawal of the Maize Board. Its positive coefficient shows that past deviations from the expected price have affected farmers' decisions less post-1996. This essentially means that price risk has affected farmers' decisions less since the introduction of SAFEX.

To test whether the introduction of SAFEX has improved farmers' ability to manage risk, we can test whether the coefficients on the respective terms add up to zero. F-statistics for this test are displayed in Table 2 and it is clear to see that we cannot reject the null hypothesis that the introduction of SAFEX has not eliminated price risk. So, we can say that, while the withdrawal of the Maize Board has resulted in an increase in price risk, the existence of SAFEX has allowed farmers to deal with this risk so that it does not adversely affect their optimal planting decisions. This result is robust across specification and estimation method.

Before we move onto our conclusion and discussion of policy implications we need to make an important note. Throughout this discussion we have implicitly made use of the *ceteris paribus* assumption. Most importantly, we have assumed that farmers' subjective uncertainty has remained relatively unchanged. That is to say that the attitude farmers had towards risk in 1971 is exactly the same as their attitude in 2008. While this is not completely unreasonable, the cultural and political changes that have happened in South Africa over this period are substantial and may have changed risk attitudes as a result.

In this section we have tried to answer our three questions empirically. We can conclude that farmers are risk averse and that there are positive wealth effects, which may be evidence of DARA. Farmers

did not seem to respond to both the “*voorskot*” and the futures price. Finally, we found robust evidence that SAFEX has allowed farmers to manage price risk even in the presence of more volatile prices.

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## **IX Conclusion**

We have developed a model to test the impact of the deregulation of the maize industry on planting decisions made by South African farmers and empirically tested the model using an aggregate data panel across four regions of South Africa. Our main findings are that South African maize farmers are risk averse and exhibit positive wealth effects, which is consistent with DARA preferences, and that the introduction of SAFEX has reduced farmers' acreage response to risk.

The result with respect to the price risk management function performed by SAFEX is certainly one that will please advocates of the free market; while we noticed a distinct increase in the volatility of prices after the withdrawal of the Maize Board our results indicate that the presence of SAFEX has helped to nullify this effect. This is in line with the claims made by UNCTAD (2007), which we set out to test.

While this result is encouraging, combining it with the finding of positive wealth effects allows for profound policy implications. Assuming that these positive wealth effects are equivalent to DARA, we can say that poor farmers are affected more by risk than wealthy farmers. Even if this result is not due to DARA, given that it is obtained from the maximisation of expected utility, an increase in wealth can at least counteract the effect of risk on utility.

Therefore, any form of wealth transfer to farmers will decrease their risk aversion (i.e. decrease their disutility from risk). In terms of the way we have defined wealth in our analysis, this could be in the form of land redistribution or an increase in the productivity (value) of land. Besides, it is likely that poorer farmers have inferior access to futures markets than rich farmers to account for this risk. Together with better access, poorer farmers need to be educated in the use of futures markets, thereby reducing the subjective uncertainty associated with them.

While these recommendations are fraught with political, cultural and economic complications, we can state them as definite advantages. We cannot say whether these advantages outweigh potential

disadvantages, but that does not take away from the fact that wealth and access to hedging instruments increase farmer welfare in the form of less risk and lower disutility of risk.

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## Appendix

The variance of the product of two independent random variables

It can be shown that

$$(A1) \quad \frac{\text{Var}(X \cdot Y)}{E(X \cdot Y)} = \frac{\text{Var}(X)}{E(X)} E(Y) + \frac{\text{Var}(Y)}{E(Y)} E(X)$$

In our example therefore,

$$(A2) \quad \frac{\sigma_{lt}}{E(p)E(y_l)} = \frac{\text{Var}(py_l - c_l)}{E(p)E(y_l)}$$

$$(A3) \quad \frac{\sigma_{lt}}{E(p)E(y_l)} = \frac{\text{Var}(py_l) + \text{Var}(c_l) - 2\text{Cov}(py_l, c_l)}{E(p)E(y_l)}$$

Assuming costs are known we have

$$(A4) \quad \frac{\sigma_{lt}}{E(p)E(y_l)} = \frac{\text{Var}(py_l)}{E(p)E(y_l)}$$

Substituting (A1) into (A4) we get

$$(A5) \quad \frac{\sigma_{lt}}{E(p)E(y_l)} = \frac{\sigma_t^p}{E(p)} E(y_l) + \frac{\sigma_{lt}^y}{E(y_l)} E(p)$$

Or,

$$(A6) \quad \sigma_{lt} = \sigma_t^p E(y_l)^2 + \sigma_{lt}^y E(p)^2$$

Decomposing the  $\frac{\partial A_l}{\partial \sigma_l} \sigma_{lt}$  term

From (A6) we have

$$(A7) \quad \frac{\partial A_l}{\partial \sigma_l} \sigma_{lt} = \frac{\partial A_l}{\partial \sigma_l} (\sigma_t^p E(y_l)^2 + \sigma_{lt}^y E(p)^2)$$

Using the Chain Rule,

$$(A8) \quad \frac{\partial A_l}{\partial \sigma_l} \sigma_{lt} = \frac{\partial A_l / \partial \sigma_l^p}{\partial \sigma_l^p / \partial \sigma^p} (\sigma_t^p E(y_l)^2) + \frac{\partial A_l / \partial \sigma_l^y}{\partial \sigma_l^y / \partial \sigma^y} (\sigma_{lt}^y E(p)^2)$$

Using (A6) again,

$$(A9) \quad \frac{\partial A_l}{\partial \sigma_l} \sigma_{lt} = \frac{\partial A_l / \partial \sigma_l^p}{E(y_l)^2} (\sigma_t^p E(y_l)^2) + \frac{\partial A_l / \partial \sigma_l^y}{E(p)^2} (\sigma_{lt}^y E(p)^2)$$

$$(A10) \quad \frac{\partial A_l}{\partial \sigma_l} \sigma_{lt} = \frac{\partial A_l}{\partial \sigma^p} \sigma_t^p + \frac{\partial A_l}{\partial \sigma^y} \sigma_{lt}^y$$

*Q-statistic (Portmanteau test statistic for white noise) Test Results*

*Table 3*

	p-value for Q-stat (1)	p-value for Q-stat (2)	p-value for Q-stat (4)	p-value for Q-stat (6)
Region 1	5.56E-08	0.007729	0.000313	0.000623
Region 2	5.20E-06	0.079933	0.175874	0.066805
Region 3	0.000441	0.383054	0.360121	0.126724
Region 4	1.70E-08	0.855749	0.889233	0.894843

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