Price Discovery and Price Risk Management Before and After Deregulation of the South African Maize Industry

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Abstract

The withdrawal of the Maize Board in 1996 meant that farmers could no longer rely on its pre-planting price or “voorskot” 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 without the need for regulation.

JEL Classification: Q11, Q13, Q18, C33

1 Introduction

Between 1937 and 1996 all aspects of maize marketing in South Africa were controlled by the Maize Board. Its pre-planting price simultaneously reduced price risk and provided a price discovery service.1 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).2 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

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2For more information on the formation and role of SAFEX, see Gravelet-Blondin (2001) and SAFEX (2009).
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.

1. Are South African maize farmers risk averse and, if so, do they exhibit decreasing aggregate risk aversion (DARA)?
2. Have farmers’ acreage responses to expected prices changed since the withdrawal of the Maize Board?
3. 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. Moreover, we find that yield risk has at least as significant an impact on farmers’ decisions as price risk.

We begin by reviewing 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.

2 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. 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 $\frac{\partial^2 u(Y)}{\partial Y^2} / u(Y)$, 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 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. We choose not to restrict ourselves to CARA, which 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.

Futures markets emerged as an alternative to commodity stabilisation schemes after 1985 when a general consensus emerged that these programs had failed (Gilbert, 1995). 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.

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, this research attempts to explain why farmers' actual behaviour deviates from that predicted by the respective models.

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.

3In our development of the econometric model, we derive an expression, which demonstrates this point very clearly.
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, while allowing for price expectations to differ.

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.4 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

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4Coyle (1992) shows this more rigorously.
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.

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. 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 Growe (2007), Ueckermann et al (2008) and Woolverton and Skyuta (2009).

3 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 \( i = 1, ..., n \) crops where \( p_i \) is the market price per unit of crop \( i \), \( Y_i \) the yield of crop \( i \), \( A_i \) the acreage allocated to crop \( i \) and \( c_i \) the cost per acre to produce crop \( i \). \( p = (p_1, ..., p_n) \) and \( Y = (Y_1, ..., Y_n) \) are unknown at the time of planting whereas \( c = (c_1, ..., c_n) \) is assumed to be known. The household chooses \( A = (A_1, ..., A_n) \) 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 \( f = (f_1, ..., f_n) \) is the futures price at planting time for crop \( i \) at harvest time and \( h = (h_1, ..., h_n) \) is the amount of contracts per crop entered into when planting.\(^6\) 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 \( h_i \).

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.\(^7\)

\[ \max_G \text{EU}(G) \]

\(^5\)Wu and Adams (2002) focus on environmental factors.

\(^6\)In South Africa, prior to 1996, we can interpret this as the “voorskot”. We, therefore, use the term expected price and futures price interchangeably.

\(^7\)The number of contracts (long or short) a farmer can purchase is restricted by factors such as margin requirements and transaction costs.
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
\[
\max_{A,h} EU(w + \sum_{i=1}^{n} p_i Y_i A_i - \sum_{i=1}^{n} c_i A_i + \sum_{i=1}^{n} (f_i - p_i) h_i)
\]

The first-order conditions are
\[
\frac{\partial EU(·)}{\partial A} = E((p_y - c) \frac{\partial U}{\partial w}) - \lambda \frac{\partial g(A)}{\partial (A)} = 0 \tag{1}
\]
\[
\frac{\partial EU(·)}{\partial h} = E((f - p) \frac{\partial U}{\partial w}) - \mu \frac{\partial k(h)}{\partial (h)} = 0 \tag{2}
\]

\( \lambda \) 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 \( A^*(w, \bar{\pi}, \sigma, f) \) \( \bar{\pi} = (\bar{\pi}_1, ..., \bar{\pi}_n) \) with \( \bar{\pi}_i = E(p_i Y_i - c_i) \), which is the expected profit for crop \( i \) based on expected prices and expected yields. \( \sigma = (\sigma_1, ..., \sigma_n) \) is the variance-covariance matrix of profits\(^8\). \( f \) is the expected price and \( w \) is wealth.

\( A^*(w, \bar{\pi}, \sigma, f) \) is homogenous of degree zero in \( (w, p, c, f) \) for all risk preferences expressed by \( U(·) \). 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.\(^{10}\)

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.

\[
\frac{\partial A^*}{\partial \bar{\pi}} \left( \frac{\partial g(A)}{\partial A} \right) - \frac{\partial A^*}{\partial w} \left( \frac{\partial g(A)}{\partial (A)} \right) A = 0 \tag{3}
\]

\(^8\)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.

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

\(^{10}\)This, however, is not always the case. Positive wealth effects are necessary, but not sufficient for DARA.
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 \( \frac{\partial A^*}{\partial \pi} \) and \( E[\pi] \) from (1) and (2), respectively we obtain the following expression:\(^{11}\)

\[
\frac{\partial A^*}{\partial \pi}(\bar{\pi} - \Gamma E(f - p)) - \frac{\partial A^*}{\partial w}(\bar{\pi} - \Gamma E(f - p))A = 0
\]

where

\[
\Gamma = \frac{Cov((py - c), \frac{\partial U}{\partial w})}{Cov((f - p), \frac{\partial U}{\partial w}) - \mu\left(\frac{\partial k(h)}{\partial w}\right)}\text{ for } Cov((f - p), \frac{\partial U}{\partial w}) \neq 0, \mu(\frac{\partial k(h)}{\partial w})
\]

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

\[
\frac{\partial A^*}{\partial \pi} = 0
\]

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, \( p \) and \( c \) 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 \( E(f - p) = 0 \), 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.

However, \( \frac{\partial A^*}{\partial \pi} > 0 \), 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 \( E[p|I]\). This means that some farmers may believe the futures price is an underestimate and others may believe it is an overestimate (i.e. \( E[p|I]\) \( \neq f\)). In practice, different farmers (and market players in general) have different information at their disposal. Also, they may have different ways of interpreting this information. This means that different market players’ rational expectations of the future spot price may be different.\(^{12}\) 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 \( Cov((py - c), \frac{\partial U}{\partial w}) \) and \( Cov((f - p), \frac{\partial U}{\partial w}) \) are negative. If farmers hold a short position, \( \mu(\frac{\partial k(h)}{\partial w}) \) will be positive, making \( \Gamma > 0 \).\(^ {13}\) If, however, farmers speculate by taking a long position and \( \mu(\frac{\partial k(h)}{\partial w}) \) 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 (i.e. \( E[p|I]\) \( > f\)). This means that \( E(f - p) \) and \( \Gamma \) will always have opposite signs and, hence, the \( \Gamma E(f - p) \) 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 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.

\(^{11}\)We also require the fact that \( E(XY) = Cov(X, Y) + E(X)E(Y)\).

\(^{12}\)This relates to the Grossman and Stiglitz’s (1989) idea of information asymmetry.

\(^{13}\)An increase in \( h \) corresponds to the farmer holding more (fewer) short-position (long-position) contracts.
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 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.

4 Econometric Model

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

\[
A_{ilt} = a_i + \left( \frac{\partial A_i}{\partial w} w_{lt-1} + \sum_{j=1}^{n} \frac{\partial A_i}{\partial \bar{\pi}_{jit}} \bar{\pi}_{jit} + \sum_{k \geq j}^{n} \frac{\partial A_i}{\partial \sigma_{jkt}} \sigma_{jkt} + \sum_{j=1}^{n} \frac{\partial A_i}{\partial f_{jit}} f_{jit} \right)
\]  

(6)

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. Whether or not individuals accept this futures price as the future spot price can be seen via their acreage decision This is the crux of our second research question. The fact that different individuals may have different expectations of the future spot price (and, hence, how well the futures price represents this) is accounted for by allowing for farmer heterogeneity.

Using the standard production theory result that \( \frac{\partial A^*}{\partial \sigma} = \frac{\partial A^*}{\partial \bar{\pi}} - \frac{\partial A^*}{\partial w} \cdot A^* \) (Mas-Collel et al., 1995: 71), which applies for all risk preferences and letting \( \bar{\pi} \), where is the wealth compensated acreage decision, (6) becomes

\[
A_{ilt} = a_i + \alpha_{il}(w_{lt-1} \sum_{j=1}^{n} A_{ij} \bar{\pi}_{jlt}) + \sum_{j=1}^{n} \beta_{il} \bar{\pi}_{jlt} + \sum_{k \geq j}^{n} \frac{\partial A_{il}}{\partial \sigma_{jkt}} \sigma_{jkt} + \sum_{j=1}^{n} \frac{\partial A_{il}}{\partial f_{jlt}} f_{jlt}
\]  

(7)

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),

\[
a_i + \alpha_i(w_{lt-1}A_{il}) + \beta_i \bar{\pi}_{lt} + \frac{\partial A_{il}}{\partial \sigma_{lt}} \sigma_{lt} + \frac{\partial A_{il}}{\partial f_{lt}} f_{lt}
\]  

(8)
To be able to test the respective effects of yield and price variance the term can be decomposed into a variance in prices \( \sigma_p^2 \) and a variance in yields, \( \sigma_y^2 \). There is no straight-forward expression for the variance of the product of random variables, but it is shown in the Appendix that

\[
\sigma_{yt} = \sigma_p^2 E(y)^2 + \sigma_y^2 E(p)^2
\]  

(9)

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 coefficient from equation (8) In the Appendix we show that

\[
\frac{\partial A_t}{\partial \sigma_{yt}} = \frac{\partial A_t}{\partial \sigma_p^2} \sigma_p^2 + \frac{\partial A_t}{\partial \sigma_y^2} \sigma_y^2
\]

(10)

Substituting this into equation (8) gives us the following

\[
A_{yt} = a_i + \alpha_1(w_{i-1}A_{i-1} \bar{p}_{jt}) + \beta_1 \bar{p}_{jt} + \frac{\partial A_t}{\partial \sigma_p^2} \sigma_p^2 + \frac{\partial A_t}{\partial \sigma_y^2} \sigma_y^2 + \frac{\partial A_t}{\partial f} f_t
\]

(11)

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

5 Data

We create a panel over four regions of South Africa for the period 1971-2008 using aggregate data\(^{15}\). 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.

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. 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.

\(^{14}\)This assumes independence of yields and prices since the yields of one farmer will not influence the price and the price can obviously not affect yields.

\(^{15}\)Throughout, a year written as 1971 will refer to the 1970/1971 season.
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 “voorkus” 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.

The variance of prices is then calculated as follows

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

Where the $\omega_j$ are 0.5, 0.33 and 0.17 respectively.\(^{16}\) $p_{i,t-j}$ 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.\(^{17}\) While the weights appear 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).

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

No per acre cost data is available for South African provinces or South Africa as a whole. However, an index of input prices for South Africa is available in the Abstract of Agricultural Statistics 2009.\(^{18}\) 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.

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.

6 Panel Data Techniques

Our panel is longer than it is wide (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. As stated by Kiviet (1995: 54), when the standard panel data approaches are applied to dynamic models that are not large (as...)

\(^{16}\)These are the weights used by Chavas and Holt (1990: 533), who claim that their results were robust to several different weight combinations.

\(^{17}\)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.

\(^{18}\)The input price index includes animal feed, which we exclude and then weight up fertilizer and seed costs to make up the difference.
is the case here), estimators can be seriously biased. Below we investigate the techniques necessary to deal with such a dataset.

Preliminary estimations using a random effects model all yielded a rho value of zero. This means that there is no need to account for the effects of variables that vary across individuals, but not across time using a random effects model. Moreover, our dataset may be prone to autocorrelation, which can be dealt with using variations of the fixed effects model. While the SUR model could also have been used, techniques to account for autocorrelation appear restricted to datasets with N larger than T (see Baltagi and Pirotte (2011)). Therefore, we start our econometric analysis with the standard fixed effects regression.

\[ y_{it} = \alpha + X_{it} \beta_1 + Q_{it} \beta_3 + u_t + v_{it} \]

While the term allows us to account for unobservable province-specific effects, which may otherwise cause heteroscedasticity, the may violate the assumption of no serial correlation due to serially correlated omitted variables or transitory variables whose effects last more than one period (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.

\[ \hat{v}_{it} = p \hat{v}_{i,t-1} + \epsilon_{it} \]

If \( p \) 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. 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 (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 we can make the following transformation.

\[ y_{it} - p y_{i,t-1} = \alpha(1 - p) + (X_{it} - pX_{i,t-1}) \beta_1 + (Q_{it} - pQ_{i,t-1}) \beta_3 + u_t(1 - p) + \epsilon_{it} \]

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

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

20 While the effects may still be significant for T=15, T=20 is sufficiently large (Arellano, 2003: 87).
serially uncorrelated errors where

\[
C = 
\begin{pmatrix}
(1 - p^2)^{\frac{1}{2}} & 0 & 0 & \ldots & 0 & 0 \\
-p & 1 & 0 & \ldots & 0 & 0 \\
0 & -p & 1 & \ldots & 0 & 0 \\
0 & 0 & -p & \ddots & \vdots & \vdots \\
\vdots & \vdots & \ddots & \ddots & 1 & 0 \\
0 & 0 & 0 & \ldots & -p & 1
\end{pmatrix}
\]

Using the inverse of the covariance matrix of the transformed errors and initial estimates for ,
the model can be estimated using Generalised Least Squares (GLS).

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

## 7 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 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 3 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.

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 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)\(^{21}\) 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 hetero-
genosity and, hence, our use of a fixed effects regression is justified. 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.

\(^{21}\)While the Maize Board was withdrawn in 1996, the first SAFEX determined expected price was for the 1996/1997
season.
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.\textsuperscript{22}

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 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.\textsuperscript{23}

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 versus the alternative that one of these coefficients is different from zero.\textsuperscript{24} 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.

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 4 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.

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

\textsuperscript{22}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.

\textsuperscript{23}Perhaps this is technically incorrect due to the fact that the test has two-sided alternative, but take the liberty nonetheless.

\textsuperscript{24}i.e. $H_0: \alpha_l = \frac{\partial A_l}{\partial \sigma_p} = \frac{\partial A_l}{\partial \sigma_y} = 0$
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 $\sigma_t^2 \cdot D97$ 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.

8 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.

References


Table 1: Mean Wealth per Region

<table>
<thead>
<tr>
<th>Region</th>
<th>Mean wealth (R '000000)</th>
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<tbody>
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<td>1</td>
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<tr>
<td>2</td>
<td>392</td>
</tr>
<tr>
<td>3</td>
<td>9.16</td>
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<tr>
<td>4</td>
<td>93.2</td>
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Source: Own calculations from various issues of the Census of Commercial Agriculture

Table 2: Regression Results

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F for no FE
Serial correlation statistic $\pm$
F for variances and wealth jointly equal to zero
F for variances jointly equal to zero
F for equality of variances

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

* Wooldridge (2002) values in columns (1),(2),(4) and (6); Baltagi-Wu (1999) LBI statistic in columns (3),(5),(7)
* No critical values available, but a value close to zero indicates positive serial correlation.
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<td>(84,853)</td>
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F for no FE
Serial correlation statistic*

21.66*** 47.07*** 21.94*** 43.17***
0.119 0.589* 0.0418 0.550*

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

1.256328 0.07236 2.158951 0.047912

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1
* No critical values available, but a value close to zero indicates positive serial correlation.

Woolridge (2002) values in columns (1),(2),(4) and (6); Baltagi-Wu (1999) LBI statistic in columns (3),(5),(7)
Table 3: Q-statistic (Portmanteau test statistic for white noise) Test Results

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<tr>
<th>Region</th>
<th>p-value for Q-stat (1)</th>
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<td>0.383054</td>
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<td>0.126724</td>
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<td>1.70E-08</td>
<td>0.855749</td>
<td>0.889233</td>
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Table 4

<table>
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<th>H₀: Variance jointly insignificant</th>
<th>Reject (positive coefficient)</th>
<th>Do not reject</th>
</tr>
</thead>
<tbody>
<tr>
<td>Reject (negative coefficient)</td>
<td>Risk averse and DARA and/or non-DARA wealth effects</td>
<td>Risk averse and CARA</td>
</tr>
<tr>
<td>Do not reject</td>
<td>Risk neutral and significant non-DARA wealth effects</td>
<td>Risk neutral</td>
</tr>
</tbody>
</table>

Figure 1: Areas Planted to Maize

Source: SAGIS
Figure 2: Expected Price and Producer Price of Maize

Source: Abstract of Agricultural Statistics and SAFEX

Figure 3: Yield Residuals

Source: Own calculations using data from the Abstract of Agricultural Statistics 2009