

# **AGRICULTURAL SUPPLY RESPONSE FOR SUNFLOWER IN SOUTH AFRICA (1947–2016): THE PARTIAL NERLOVIAN FRAMEWORK APPROACH**

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## **Abstract**

The study estimates sunflower supply response in South Africa using time series data from 1947 to 2016, and modelled through the Nerlovian Partial Adjustment approach. The short- and long-run price elasticities of 0.238 and 0.313 respectively, suggest that farmers do not easily adjust acreage devoted to sunflower given price changes, which is an indicator of the influence of other non-price factors. An adjustment coefficient of 0.272 estimates that the time taken to adjust from the actual acreage level to the desired acreage level is slow, at 27% per year. The estimated elasticities, though inelastic, provide some scope for using a pricing policy, as well as integrating non-market factors, to influence supply of sunflower that can reduce the country's dependence on imports, as well as sustain the industry. This would facilitate decision-making of sunflower producers to spearhead internal and external adjustment processes. The study contributes to a growing body of literature on agricultural supply response due to economic and non-economic supply determinants, thus providing evidence-based macro-economic tools towards agricultural policy-making and reform process.

Key words: supply response; elasticities; sunflower; acreage; Nerlovian partial adjustment

## **Introduction**

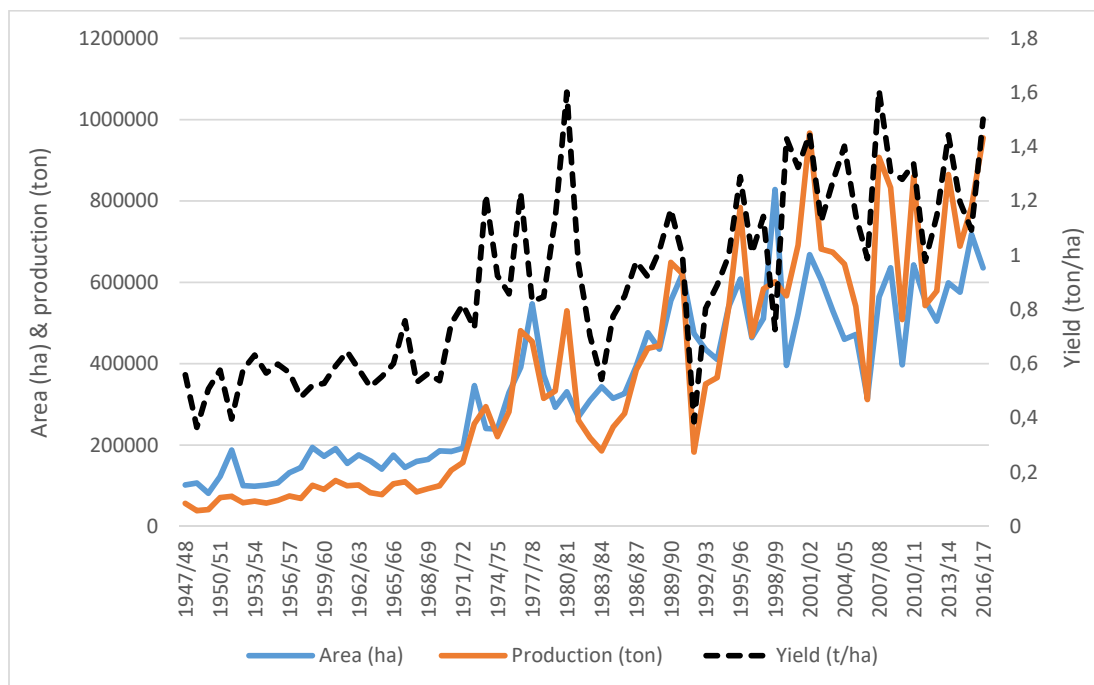
Sunflower is a vital field crop that is produced in South Africa, coming third after maize and wheat. It accounts for approximately 60% of oil seeds produced locally and adds to the agricultural Gross Value of Production (GVP), as well as in the value-chains of other products and commodities (Van Schalkwyk 2003; SAGIS; 2006; GRAINSA 2007). In South Africa, it is the main source for animal protein feed producers and sunflower oil for industrial and human

utilisation (AFMA 2007). South Africa has classified sunflower oil as a basic food product, mainly used for home consumption. A large percentage of the South African sunflower crop is absorbed by the processing industry for conversion to mainly cooking oil. Globally, sunflower production makes up around 8% of the total global vegetable oil production (Konyali 2017). In South Africa, sunflower is cultivated throughout the country. However, in recent years, approximately 80% of the area under sunflower production has been located in the low rainfall areas of the North West and Free State provinces (SAGIS 2018; BFAP 2015).

Total sunflower seed production in South Africa is considerably lower than the total consumption, while average yields are approximately 20% below the international average. This has resulted in the country being a net importer of sunflower products that include seed, oil and cake to keep pace with increasing domestic demand of these products. For example, BFAP (2015) indicated volatility in the production levels of sunflower from the early 1990s, virtually with no observed real growth, while at the same time, domestic demand for sunflower products increased by about 40% over time. In addition, the national average yield maintained is between 1t/ha and 1.3t/ha over a progression of two decades from 1999 to 2019 (Pilorgé 2020). There are increasing concerns on the failure of domestic production to match the level of sunflower produced to help close the import gap, as well as taking advantage of the approximately double the amount of crushing capacity available as the amount of sunflower seed that is produced locally.

The poor yields, in addition to sunflower competing for resources with other summer field crops such as maize and soybean are major factors that have caused poor growth in production to meet the increasing demand. This is despite sunflower having lowest risk as compared to other summer crops (Bezuidenhout 2019), as well as ability to achieve higher and consistent yields under unfavourable weather conditions, low-input and marginal cropping conditions (BFAP 2015). According to Adeleke and Babalola (2020), sunflower has strong adaptive mechanisms to grow in complex environments, and requires lower levels of fertility as compared to maize, wheat, and other crops to enhance their yields. It can also be incorporated into local cropping systems to enhance soil health and increased biodiversity in a crop rotation system.

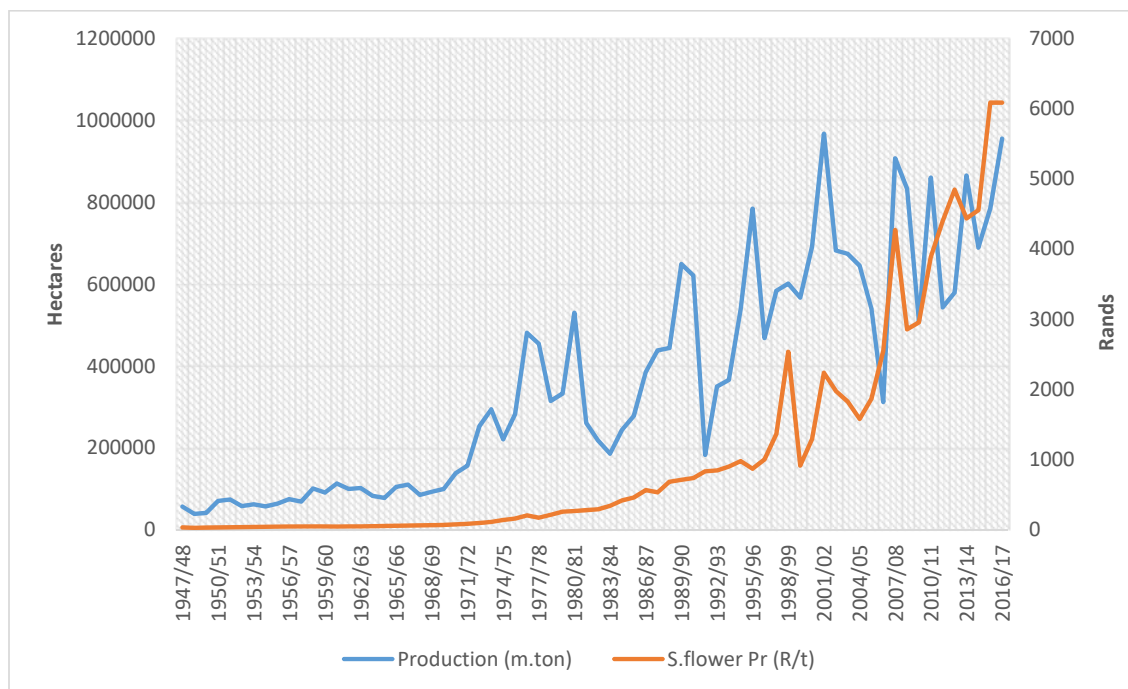
Figure 1 shows historical area planted, production and yields for sunflower from 1947 to 2016.



**Figure 1:** Historical area planted, production and output per hectare for sunflower: 1947-2016  
*Source: Authors' compilation, 2020*

Generally, there was an increase in the area, production and average yields of sunflower over time in the country, although with volatility. The observed volatility patterns are somehow attributed to several reasons that include challenges that producer face, and these include; negative attitudes on historical sunflower production experiences like poor emergence, pests and diseases as well as falling over problems, among other related constraints (BFAP 2015). Based on trends depicted in Figure 1, concerns still arise as to why the country is failing to meet domestic demand and remains a net importer of the commodity, yet area, production and yields have been increasing. Thus, it is imperative to understand the dynamics leading to such trends happening, especially given that the output prices have been increasing over time, a condition that could have led to increased sunflower output (Figure 2).

From a general theoretical perspective, several factors such as own price, cost of production, prices of competing products, technology, government policies, and availability of factors of production could influence supply. It is not clear what the magnitude of supply response has been, and why local supply remains lower than consumption of sunflower seed.



**Figure 2:** Historic sunflower prices and production: 1947-2016  
 Source: Authors' compilation, 2020

The trend shows a general increase in sunflower production even when the prices were not increasing at the same pace. Despite a huge potential for sunflower to contribute towards satisfying the future oil demand, the industry is still faced with the task of improving yield whilst making sure the oil content is not compromised (BFAP 2015). In South Africa, before democracy, and after the restructuring in the country's agricultural sector around 1996, the industry was exposed to the international oilseed complex market, which brought opportunities and challenges. This is discussed in the section that follows.

***The effects of the 1996 deregulation on the sunflower industry***

Before 1996, the agricultural marketing policy in South Africa was largely regulated under the Marketing Act (Act 59 of 1968, as amended), which contained “*inter alia*, a list of potential policy instruments that could be used to control the marketing of a commodity” (Kirsten and Vink 2000). The Act also gave the Minister of Agriculture authority to appoint commodity control boards to regulate the marketing of such products, thus giving birth to 23 control boards. The Oilseed Board was one board under this proclamation, with a mandate to exclusively regulate the marketing of oilseeds and oilseed products. The board also determined producer and selling prices of all oilseeds depending on local demand and dynamics, as well as export pool prices (Vink and Kirsten 2002).

In 1996, South Africa liberalised the agricultural sector. This process led to the replacement of the Marketing Act (Act 59 of 1968, as amended) by the Marketing of Agricultural Products Act, No. 47 of 1996. In this process, South Africa made considerable changes in economic policy in line with the international movement towards deregulation<sup>1</sup> and the liberalisation of the economy. This led to termination of the functions of the Oilseed Board; hence, the oilseed industry was no longer regulated, leading to formal trading of the oilseed on the Agricultural Marketing Division of the South African Futures Exchange (SAFEX). As such, local oilseed producers and processors were fully exposed to international markets where domestic commodity prices followed international commodity prices very closely (Townsend 1997; SAGIS 2006). This therefore meant considerable changes in the pricing system of sunflower seed. And since the sunflower sector was now characterised by a deregulated market with uninformed producers, who were no longer protected by the Marketing Boards (GRAINSA 2007), the role players in the industry had to make decisions concerning pricing, production and product policies. However, it remains unclear how these reforms, the pricing regimes and other non-economic reforms have influenced sunflower production in the country over time. Rao (2003) argues that “the impact of liberalisation on growth of agriculture crucially depends on how farmers respond to various price incentives”.

It is thus imperative to enhance an understanding of the inherent and structural factors influencing sunflower production, as well as accurate interpretation of the effects of such changes in these factors. These factors, which include commodity price, area sown, rainfall, fertilisers, improved seeds, technology, substitutability between crops, etc., influence growth of sunflower production in different degrees. Moreover, the dynamic environment in which South African producers of sunflower function necessitates an understanding of supply patterns (SAGIS 2006) and factors influencing supply. This is because farmers respond differently to changes in policy, economic and non-economic issues, which indeed have implications to their production or capability (Okoko et al. 2008). As stated by Mushtaq and Dawson (2002), supply response is amongst the most important issues in agricultural development economics. This is because farmers’ responsiveness to economic incentives largely influences how agriculture contributes to the economy.

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<sup>1</sup> The major influential changes in the global sunflower market were characterised by the transformation of a highly regulated international industry to an essentially free one (SAGIS, 2006; Meyer, 2005).

A quantitative estimation of various factors influence growth of sunflower output is helpful in re-orienting policies and programmes geared towards achieving increased production (Drimie 2016). Otherwise, making use of agricultural policy instruments to influence agricultural production, without support of empirical insights of supply response determinants leaves the possibility that these policy instruments may be inappropriately used, consequently leading to unintended results (Muchapondwa 2009). Hence, knowledge of supply responsiveness will facilitate and better inform agricultural policies as well as to serve as a decision-making tool, particularly given the ever-changing economic and non-economic changes.

Previous studies conducted to estimate supply response in South Africa include Schimmelpfennig, Thirtle, and Van Zyl (1996); Ogundeji, Jooste and Oyewumi (2011); Shoko, Chaminuka, and Belete (2016; 2019). None of the existing studies focussed on analysing supply response of sunflower, despite its importance in the country. The study analyses sunflower farmers' supply response to changes in the price and non-price incentives, as well as estimating short- and long-run elasticities of sunflower in South Africa using time series data from 1947 to 2016. The study deviates from past studies that mainly focused on price incentives, and contributes to the on-going debate by accounting for non-price factors. The working hypothesis is that sunflower farmers' degree of supply responsiveness is inelastic. In so doing, the study will contribute to a growing body of literature regarding supply response due to economic and non-economic supply determinants and add a range of macro-economic tools to the policymaking process.

### **Theoretical framework**

Economic theory dictates that price is a major determinant of supply of any commodity. Therefore, pricing policy can be one of the tools used to control the output of a crop, or any other commodity, *ceteris paribus*. The main objective of the agricultural price policy is to stimulate production, particularly when the technology for that purpose is available (Kahlon and Tyagi 1983). However, it is important to note that this policy is only relevant where farmers react rationally to price changes. This, therefore, suggests a need for reliable estimates of price elasticities of supply, if an effective agricultural price policy is to be developed and used to stimulate agricultural production. The supply response studies provide an estimation of how crop output responds to price and non-price incentives such as price, technology and weather (Yotopoulos and Nugent 1976).

Knowledge on the magnitude of the elasticity coefficient enables the policy makers to have a precise idea as to what level of support would be necessary to influence growth in agricultural production. Furthermore, supply elasticities indicate the magnitude and speed of output adjustment responsiveness associated changes in economic and non-economic factors. This is central for policy consideration as it measures the ability of farmers to adjust production to changing economic and non-economic conditions. It is for this reason that supply response studies, like the current one have an important role in the context of formulation of appropriate agricultural policies and programmes, in as much as they also have implications on research and development.

### **Methods and procedures**

Two frameworks largely used in supply response analysis include; a Nerlovian model and the derived supply function approach based on the profit-maximizing framework (Ball 1988; Sadoulet and de Janvry 1995). The current study focuses on estimating farmers' output reaction to economic and non-economic incentives, hence, the Nerlovian approach was selected as the approach choice.

#### ***The Nerlovian Model***

Most of the studies that have conducted supply response assessments have used the Nerlovian Model developed by Nerlove (1956), a model that has been considered as the “most influential and successful” based on the number of studies which have utilised this approach (Braultke 1982). It enables estimation of short- and long-run elasticities, giving the flexibility to introduce non-economic variables in the model.

In South Africa, one study by Shoko, Chaminuka, and Belete (2016) applied the model to estimate maize supply response. The study found both the price and non-price elasticities to be inelastic, although the non-price factors had generally higher elasticities than the price variable. This was the case in both the short- and the long-run. This indicated the relative importance of non-price factors in influencing maize supply decisions of farmers.

In the district of Tamil Nadu India, Sumathi et al. (2019) applied the model to time series data from 1991 to 2011 to determine the supply response of maize. The short- and long-run elasticities differed between price and non-price factors. Lagged price was found to have relatively higher elasticities than non-price factors. This was found to be the case in three

models estimated, the acreage response model, the yield response model and the production response model. This indicated that price played a significant role in the supply of maize to the market and could be used as a tool to affect farmers' decisions of supply. Similarly, in Cote d'Ivoire and Nigeria, Salifou et al. (2019) found that price played an important role of influencing smallholder farmers' decisions to produce and supply cocoa. In these countries, own price of cocoa as well as the price of coffee, a competing crop greatly influenced producer decisions. The long-run elasticities were however, not estimated.

The same model was applied to potato production in Iraq over the period 1989 to 2018 by Madlul et al. (2020). The results indicated that both the short- and long-run elasticities were inelastic. This was the case, for price and non-price factors. This meant that potato producers responded little to changes in price and non-price factors. The expected relationships according to economic theory were however evident. In Pakistan, Rani et al. (2020) used time series data various agricultural crops<sup>2</sup> from 1981 to 2015 to estimate the supply response. The authors found the short-run supply elasticities in relation to price ranged between 0.1 and 0.5 for, suggesting that in the short-run, the supply of these crops responded slowly to price changes. The long-run elasticities were however not estimated.

Other recent applications of the Nerlovian framework include Le and Ngo (2020) in Vietnam, investigating the supply response of black tiger shrimp to price and non-price factors over the period 2014 to 2017. In addition, Hazrana, Kishore and Roy (2020) applied the same framework to staple food crops in India from 1999 to 2015 using an instrumental variable approach to control for endogeneity of prices. Lastly, Akber and Paltasingh (2019) investigated the relationship between price and non-price factors with the supply of apples in India. The short- and long-run elasticities of price and non-price factors were inelastic. The study also accounted for weather and price risks, and found that farmers responded relatively more to weather risks than price risks.

From these studies, the Nerlovian framework has been applied to assess the response of various agricultural commodities to price and non-price factors. Some of the studies indicate the importance of price as a tool that can be used to influence supply. However, because of the inelastic response observed for some of the commodities, the effectiveness of price to influence supply is mainly evident in the long-run, when producers are able to make changes to their

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<sup>2</sup> These crops were chickpea, lentil, mung, mash, wheat, cotton, sugarcane, maize and rice.



production activities that are difficult to make in the short-run. In the case of non-price factors, different results were obtained, with the elasticity of some non-price factors observed to be inelastic, while others were elastic. This therefore highlights the importance of differences in the nature of various commodities, as well as the context in which they are being investigated as these affect the supply response decisions of farmers.

There are two versions of the Nerlovian model; the Adaptive Expectations Model and Partial Adjustment Model, which are discussed in the subsequent sections.

#### *Adaptive Expectations Model*

This model was first suggested by Cagan (1956) and later developed by Nerlove (1956). This model is based on behavioural hypothesis stating that farmers generally react to a price they expect, which is dependent to some extent on what the previous year's price was (Nerlove 1956). The Adaptive Expectations Model is thus, based on the reasoning that hectareage devoted to a specific crop in a given year is a linear function of the expected price in that year (Kmenta 1971). It is, therefore assumed that farmers are likely to respond to most recent prices to determine the acreage they need to devote to a given crop.

#### *Partial Adjustment Model*

In this model, farmers are always trying to bring the actual level of farm output to some desired level, but such efforts are never completely successful, due to uncontrollable factors, such as weather (Odada 1978), as well as technological constraints, institutional rigidities or persistence of habit (Kmenta 1971). The level of crop area that farmers desire to use is dependent on the expected level of price and other non-economic variables (Nerlove 1958). This current study uses the Nerlovian partial adjustment model, which defines agricultural supply response by incorporating price expectations and the adjustment costs. The functional model can be stated as:

$$A_t^* = \phi_0 + \phi_1 P_t^* + U_t \quad 1.$$

$$P_t^* = P_{t-1}^* + \alpha(P_{t-1} - P_{t-1}^*) \quad 2.$$

$$0 < \alpha \leq 1$$

$$A_t - A_{t-1} = \delta(A_t^* - A_{t-1}) \quad 3.$$

Where

$A_t^*$  is the desired sunflower hectares in year  $t$ ;  $\phi_0$  is the constant term;  $\phi_1$  is the long-run supply response;  $P_t^*$  is the desired sunflower prices in year  $t$ ;  $U_t$  is the independent normally distributed error term;  $A_t$  is the actual sunflower hectares in year  $t$ ;  $P_t$  is the actual sunflower price in year  $t$ ;  $\alpha$  is the coefficient of expectation and lies between zero and 1;  $\delta$  is the coefficient of adjustment from the actual acreage to the desired acreage level. A coefficient close to 1 implies rapid actual acreage adjustments to the desired acreage rapidly, and if close to 0, then the adjustment to desired acreage level is slow (Leaver, 2003).

The assumption put forward by Nerlove (1958) when conducting supply response estimations is that “actual acreage changes to the desired acreage level with some lag”. It is therefore recommended to remove “unobservable variables associated with expected price and desired acreage” from equations (1) to (3). The resultant structural form equation, with variables expressed in the logarithmic is as specified in equation 4:

$$A_t = \beta_0 \alpha \delta + \beta_1 \alpha \delta P_{t-1} + [(1 - \alpha) + (1 - \delta)] A_{t-1} - (1 - \alpha) (1 - \delta) A_{t-2} + \delta [U_t - (1 - \alpha) U_{t-1}] \quad 4.$$

Equation 5 below, which specifies the final reduced form equation inclusive of non-price variables, shows the observed area ( $A_t$ ) as a function of the previous period's price ( $P_{t-1}$ ), previous area under the crop ( $A_{t-1}$ ), a set of non-price variables ( $X_t$ ) and the disturbance term  $Z_t$ :

$$A_t = b_0 + b_1 P_{t-1} + b_2 A_{t-1} + b_3 A_{t-2} + b_4 X_t + Z_t \quad 5.$$

Where:

$$b_0 = \phi_0 \alpha \delta$$

$$b_1 = \phi_1 \alpha \delta$$

$$b_2 = (1 - \alpha) + (1 - \delta)$$

$$b_3 = - (1 - \alpha) (1 - \delta)$$

$$b_4 = \alpha_2 \delta$$

$$Z_t = \delta[U_t - (1 - \alpha)U_{t-1}]$$

The reduced form, a distributed lag model has lagged dependent variable that appear as independent variables. The coefficient of each explanatory variable directly gives short-run elasticities, while the long-run elasticities are determined by dividing short-run elasticities by (1- coefficient of the lagged area variables). The underlying assumption is that all the long-run elasticities exceed short-run elasticities. In this context, an adjustment coefficient close to 1, implies that sunflower producers' adjustment to desired acreage is rapid, while a coefficient close to 0 implies the adjustment process is rather slow.

Equation 5 in its current form cannot be estimated using the Ordinary Least Squares (OLS) technique. Hence, it was transformed into the linear form by taking the natural logarithms (ln) to allow estimation of the supply response for sunflower as illustrated and discussed below.

#### ***Econometric estimation of sunflower supply response***

Unlike the Adaptive Expectations Model, the Partial Adjustment Model can be easily estimated by the Ordinary Least Squares (OLS) method; as it estimates the model parameters. It also has an error structure, which was subjected to Durbin-Watson test for serial correlation (Koutsoyiannis 1977). All other variables, excluding the time-trend and dummy variables were transformed into logarithmic form to allow direct interpretation of the coefficient of each explanatory variable as short-run elasticities. This also enabled estimation of the long-run elasticities calculated by “dividing short-run elasticities by (1 - coefficient of the lagged depended variable)”. In addition, the log transformation also stabilises any variance within the data series (Lutkepohl and Xu 2009).

The acreage response estimation, simplified from the Nerlovian partial adjustment model in section 2.3 was done using the following equation:

$$\text{Lg}A_t = \psi_0 + \psi_1 \text{Lg}P_{t-1} + \psi_2 \text{Lg}A_{t-1} + \psi_3 \text{Lg}Y_{t-1} + \psi_4 \text{Lg}R_{t-1} + \psi_5 \text{PC} + \psi_6 \text{Lg}XR_{t-1} + \psi_7 T + \psi_8 \text{TQ}_t^2 + U_t \quad 6.$$

Where:

$\text{Lg}A_t$  = log of sunflower area in hectares in time  $t$

$\text{Lg}P_{t-1}$  = log of real prices for sunflower in previous year in Rands/tonne

$LgA_{t-1}$  = log of area under sunflower in the previous year in hectares

$LgY_{t-1}$  = log of sunflower yields in the previous year measured in tonnes/ha

$LgR_{t-1}$  = log of average rainfall in the previous year measured in millimetres

$Pc$  = is policy variable treated as a dummy (1 = policy reforms; 0 = otherwise)

$LgXR_{t-1}$  = log of exchange rate (US\$ to Rand) in the previous year

$T$  = simple time trend ( $T = 1$  for 1947 to  $T = 70$  for 2016)

$TQ_t^2$  = quadratic time trend ( $T = 1$  to  $T = 4900$ )

$U_t$  = error term

### ***Selection of the output variable***

Evidence from literature on supply response studies suggest estimation of acreage rather than output response to price changes. This is because the output supplied depends on acreage under the crop in question. Generally, due to great seasonal variability of weather conditions, farmers tend to have little control over actual output due to fluctuations in crop yields. Hence, it is logical to use actual acreage as a proxy for output (Yotopoulos and Nugent 1976). The reason being that farmers are able to control acreage under which they put their crop, and once planted, cannot be varied during the production period by factors outside the farmer's control. It is for this reason that acreage planted to sunflower was considered as a proxy or approximation of the farmers expected output for the period under consideration. The choice of acreage as an output variable also follows other studies such as Nerlove (1958), Ball (1988), Leaver (2003), Conteh et al. (2014), Shoko, Chaminuka, and Belete (2016). Time series data for acreage was thus obtained for the period 1947 to 2016.

### ***Specification of the explanatory variables***

#### ***Sunflower previous year's acreage***

The inclusion of the lagged dependent variable ( $LgA_{t-1}$ ) as an explanatory variable in the model was based on the assumption that its coefficient contributes significantly to an explanation of the level of the current area put under sunflower. In this study, the coefficient of the lagged dependent variable is expected to be positive, indicating that the current area put

under sunflower is positively influenced by area put under sunflower during the previous season.

#### *Output price*

The inclusion of the price variable in the supply response function is an indication of its importance in decision-making at farm level. Economic theory dictates that the coefficient of the price variable in a supply response model be positive, *ceteris paribus*. The assumption here is that as the producer price of sunflower is increased, more is produced by increasing the area put under the crop, implying a positive relationship between sunflower price and the area allocated to the crop.

#### *Sunflower previous year's yield*

The yield of sunflower lagged by one year was included in the model as an indicator of its influence on the supply of sunflower. As suggested by King (1956), "one of the important factors affecting the difference between what a farmer expected for a price and what he received is unusual yields". He argues that acreage planted is influenced by expected price, assuming normal conditions. It is, therefore, important to determine how yields influence acreage planted through the expected price. The coefficient of the sunflower yield variable was expected to be positive, implying that if the previous period's yield of sunflower was high, then farmers will put more land under sunflower during the current period.

#### *Rainfall*

The yield of any crop is greatly influenced by weather, e.g. rainfall, among other things; hence, it was used as a proxy for weather. This variable was also lagged by 1 year, implying that the previous season's rainfall pattern serves as an indicator on how much acreage would a farmer devote to sunflower production.

#### *Policy reforms*

The deregulation and liberalisation of the country's agricultural sector around 1996 exposed the sunflower industry to the international oilseed complex market, with local commodity prices following the international commodity price patterns very closely (Townsend 1997 and SAGIS 2006). The sunflower sector was therefore characterised by a deregulated market with uninformed producers no longer protected by the Marketing Boards (GRAINSA 2007). It was

therefore necessary to include the policy variable to capture if the deregulation and liberalisation reforms that took place influenced sunflower production in South Africa. The years before the reforms took the value of 0, while years after reforms took the value 1.

#### *Time trend*

The time trend variable is included in the model to capture other variables that could influence acreage response, but are omitted in the model, for example, technological and political changes, among others. The coefficient of the trend term could be positive or negative, depending on whether the area put under sunflower is increasing or decreasing with time.

#### *Exchange rate*

The changes in the agricultural sector in the mid-1990s left the sunflower industry exposed to the international oilseed complex market, where local commodity prices followed international commodity prices very closely (Townsend 1997 and SAGIS 2006). Hence, an exchange rate is “an important mediating mechanism between global markets and local production decisions” (Schuh 1974; Chambers 1988) and is expected to influence acreage put under sunflower in the current year. Therefore, the exchange rate, lagged by one year was included in the model to capture its influence on the production of sunflower in the country.

#### *Prices of competing crops*

From a theoretical perspective, quantity produced and supplied is a function of its own and substitute prices, as well as the prices of inputs. Within the context of this study, maize and soybean were selected as possible competitive crops to sunflower. Therefore, prices of these crops were selected for the analysis. However, following a study by Shoko, Chaminuka, and Belete (2016), the study had to select the best price variable used in the analysis using a regression model based on a simple adaptive model as specified in equation 7 below.

$$A_t = \beta_0 + \beta_1 P_{t-1} + \beta_2 A_{t-1} + U_t \quad 7.$$

Where

$A_t$  is dependent variable (sunflower acreage),  $P_{t-1}$  is selected price variable in previous season,  $A_{t-1}$  is sunflower acreage in previous season, and  $U_t$  is the disturbance error term. Based on

equation 7 and using the t-tests and  $R^2$  estimates, the best price variable used in the analysis was selected.

### ***Data requirements and sources***

The study makes use of historical time series data for the period 1947 to 2016. The data were extracted from the database established and managed in the Centre of Collaboration on Economics of Agriculture Research and Development<sup>3</sup> and DAFF (2017)'s Abstract of Agricultural Statistics. The data used in this study included area and yields, prices for sunflower, maize and soybean. Data on annual inflation rate, measured by Consumer Price Index (CPI) were also obtained from the same sources. The data on exchange rate over the period under consideration were extracted from the Reserve Bank of South Africa website<sup>4</sup>. Average rainfall (mm) data were obtained for sites selected in major sunflower producing provinces of South Africa through the Agricultural Research Council's Institute of Soil, Climate Change and Water. These sites are Free State, North West, Mpumalanga, Limpopo and Northern Cape provinces.

### **Results and discussion**

The Nerlovian model was estimated in EViews 8 using an Ordinary Least Squares (OLS) method. The size of the coefficient for each independent variable denotes the size of the effect a variable has on the dependent variable, while the sign on the coefficient (positive or negative) gives the direction of the effect. The data series for the study period from 1947-2016 was tested for unit roots for the following variables; sunflower acreage (A), sunflower yields (Y), average rainfall (R), real prices for sunflower (SFP), maize (MzP) and soybean (SBP). The unit root results of the Augmented Dickey Fuller (ADF) test used for this study are presented in Tables 1 and 2. The lag length was selected based on the Akaike information criterion.

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<sup>3</sup> This builds from work on a poster presented at the 55<sup>th</sup> AEASA conference by Mamabolo *et al.*, (2017) on agricultural research data rescue through collaborative partnerships.

<sup>4</sup> <https://www.resbank.co.za/Research/Rates/Pages/SelectedHistoricalExchangeAndInterestRates.aspx>

**Table 1: Results of unit root tests in levels**

Series <sup>56</sup>	ADF test statistic	Critical value	Lag length	P-value	Conclusion
LogA	6.444487	4.096614	0	0.0001	Stationary
LogP	3.865111	4.096614	0	0.0188	Non-stationary
LogMzP	2.168266	4.096614	0	0.4992	Non-stationary
LogSBP	3.448225	4.096614	0	0.0534	Non-stationary
LogY	4.5055462	4.096614	0	0.0030	Stationary
LogR	6.822135	4.096614	0	0.0000	Stationary

Source: Authors' computations, 2020

Table 1 shows only three time-series variables that were stationary at levels; area, sunflower yields and rainfall, while real prices for sunflower, maize and soybean became stationary at first level differencing (Table 2).

**Table 2: Results of unit root test at first level differencing**

Series	ADF test statistic	Critical value	Lag length	Probability	Conclusion
LogP	10.66018	4.098741	0	0.0000	Stationary
LogMzP	8.023081	4.098741	0	0.0000	Stationary
LogSBP	11.58629	4.098741	0	0.0000	Stationary

Source: Authors' computations, 2020

### ***Selection of a price variable***

Three price variables for sunflower, maize and soybean were considered in the analysis. The best price was selected using a simple adaptive expectations regression model (as specified in equation 7 above) for each of the price variables. The regression results of each of the price variables are presented in Table 3.

<sup>5</sup> All variable include intercept and trend

<sup>6</sup> All variable are converted to logarithm form



**Table 3:** Results for selection of a price variable used in the model

Series	Coefficient		R-squared
	$P_{t-1}$	$A_{t-1}$	
Sunflower	0.384601	-0.437894	0.737086
Maize	0.344372	0.299393	0.621361
Soybean	0.339148	-0.041427	0.652384

Source: Authors' calculations, 2020

Based on the statistical comparison of the t-tests and  $R^2$  estimates, sunflower price was selected as the price parameter to be included in the specified supply response equation. In this regard, maize and soya beans price variables were thus not considered, and were excluded from the model.

**Table 4:** Regression results for sunflower acreage response: 1947-2016

Dependent Variable: LogAcreage			Included observations: 70	
Variable	Coefficient	Std. Error	t-Statistic	Prob.
Constant	3.067603	0.676875	4.532009	0.0000
LogY (previous year yield)	0.260108	0.107281	2.424547	0.0183**
LogA (previous year area)	0.121870	0.103915	1.172784	0.2454
LogP (previous year price)	0.238743	0.109657	2.177184	0.0333**
LogR (previous year rainfall)	0.344786	0.162030	2.127912	0.0374**
XR (previous years exchange rate)	0.012828	0.011601	1.105751	0.2732
Pc (policy)	-0.101686	0.055161	-1.843440	0.0701*
T (simple time trend)	0.010741	0.004310	2.491988	0.0154**
QT <sup>2</sup> (quadratic time trend)	-0.000144	7.23E-05	-1.986161	0.0515*
R-squared	0.911438	Mean dependent var		5.475994
Adjusted R-squared	0.899823	S.D. dependent var		0.271477
S.E. of regression	0.085924	Akaike info criterion		-1.951177
Sum squared resid	0.450363	Schwarz criterion		-1.662085
Log likelihood	77.29119	Hannan-Quinn criter.		-1.836346
F-statistic	78.47288	Durbin-Watson stat		1.950986
Prob(F-statistic)	0.000000			

Source: Authors' calculations, 2020

\*\*\*significant at the 1% level \*\*significant at the 5% level \*significant at the 10% level

### *Sunflower supply response results*

The results presented in Table 4 depict the acreage response of sunflower for the period 1947 to 2016. The value of  $R^2$  shows the overall fitness of the acreage equation as 0.91, implying that explanatory variables explain 91% in sunflower acreage. The F-statistic is 74.47288 and also indicates overall significant relationships ( $p < 0.0000$ ). The Durbin h-statistic is less than 1.96; hence, the null hypothesis of no autocorrelation is accepted. This means there is no evidence of serious autocorrelation in the residuals.

The lagged real price of sunflower had a positive coefficient of 0.238 at the 5% level, implying a positive influence of price on the acreage that a farmer decides to put sunflower. Indeed, the results confirm that sunflower farmers in South Africa consider the previous season price to determine acreage they devote to sunflower production, which is also in line with the theoretical law of supply. This could also explain a general increase in sunflower production as prices moderately increased over time (Figure 2). The findings however reveal that devoted sunflower acreage does not respond well to the price incentives as confirmed by the short-run elasticity of 0.238 (which shows that the sunflower acreage is inelastic to lagged real sunflower price). The results imply that a unit increase in price results in 23.8% increase in acreage devoted to sunflower production. Similar findings are also observed in other studies (e.g. Ndzinge *et al.*, 1984; Rodriguez 1985; Shoko, Chaminuka, and Belete 2016). Generally, these results suggest that the price factor is a tool that can be potentially used to influence supply of sunflower, taking into consideration that sunflower prices follow international price patterns and are therefore subjected to prevailing exchange rates.

The lagged previous year's yield variable has a positive coefficient of 0.2601 and significant at the 5% level. This suggests that farmers would allocate more acreage to sunflower if the previous yields of sunflower were high. Sumath *et al* (2019) found similar findings in their maize study. This could be attributed to the motivation that the farmers would have and would expect to even improve yield in the year of production. The fact that the prices of sunflower respond to the international market forces also means that global shortages increase local price for sunflower, hence farmers will also tend to increase acreage allocated to sunflower based on the higher previous sunflower yields.

The lagged rainfall variable had a positive coefficient of 0.344 and significant at the 5% level, suggesting a positive influence of rainfall on the acreage that a farmer allocates to sunflower

production. In this context, as rainfall is favourable, farmers would allocate more land to sunflower production in the next season, as they will be almost certain of getting a better harvest of their crop. Other studies estimating supply responses, e.g. Shoko, Chaminuka, and Belete (2016) and Conteh et al. (2014) found similar results regarding the positive influence of weather conditions towards farmers' decision to allocate more acreage to sunflower.

The policy variable was treated as a dummy variable, with 0 representing the period before the deregulations in 1996/97 period, while a value of 1 represented otherwise. With a negative coefficient value of -0.101, the variable was significant at the 10% level. The results suggest that the deregulations around 1996 going forward negatively affected acreage under sunflower production in the country. This is because the oil industry was exposed to the international oilseed complex market, which brought some challenges to sunflower production. For example, there were various changes in the pricing system of agricultural commodities, including sunflower seed and the local commodity price followed the international commodity prices very closely (Townsend 1997; SAGIS 2006). However, the result for the policy variable needs to be treated with caution, as the way it was structured assumes that there was homogeneity in policy even before 1996. South Africa underwent a period of international isolation between 1980 and 1994 (Liebenberg 2013), which could also have affected the operation of domestic markets and trade.

The time trend was included in the model to capture the effect of other non-price incentives that could have influenced the acreage allocated to sunflower in South Africa for the period under consideration. Some of these could include technological advancement, improvements in input use, management practices and so on. Both time trend variables were significant. The simple time trend variable has a positive coefficient value 0.0107 and significant at the 5% level. On the other hand, the coefficient value of the quadratic time trend variable is negative (-0.000144) and significant at the 10% level. From these results, the positive and significant relationship between acreage under sunflower and the simple time trend suggests that improvement in other non-price factors have generally led to more acreage put under sunflower production in the country. These factors could include technological advancement, which improve efficiency and productivity in sunflower production. Although positive, the magnitude of an increase in acreage under sunflower attributed to non-price related factors was low, as a unit increase in these factors only led to a 1.07% increase in acreage allocated to sunflower production.

### ***Testing validity of the supply response model***

Validity diagnostic tests were done on the supply response model to validate the quality and robustness of the model. The test tools and results of the tests are shown in Table 5.

**Table 5:** Validity diagnostic tests

<b>Test</b>	<b>Method</b>	<b>Result</b>	<b>P-value</b>	<b>Decision</b>
Normality	Jarque-Bera	6.6314	0.2363	Residuals normally distributed
Stability	Ramsey Reset	0.6665	0.5173	Stability within parameters
Heteroskedasticity	White	1.6498	0.0857	No heteroskedasticity

*Source: Authors' calculations, 2020*

From the validity tests results, the supply response model was found to be adequate for the study after satisfying the acceptable conditions of the tests.

### ***Estimated elasticities of supply***

The short-run and the long-run price elasticities of supply were computed. The distinction between short-run and long-run elasticities of supply is based on the assumption about the supply of certain factors to the industry. One advantage of the logarithmic function is that the coefficient of the independent variable is an elasticity by itself. The short- and long run elasticities of supply are shown in Table 6.

**Table 6:** Estimations of short- and long run elasticities and adjustment coefficient

<b>Elasticities</b>	<b>Independent variable</b>	<b>Short-run</b>	<b>Long-run</b>
Price	Sunflower price	0.2387	0.3135
Non-price	Yield	0.2601	0.3515
	Rainfall	0.3447	0.5260
	Policy	0.1016	0.1131
Coefficient of adjustment		0,2718	

*Source: Authors' calculations, 2020*

The short- and long price elasticities of sunflower are 0.2387 and 0.3135 respectively (see Table 6). The findings imply inelastic price elasticities implying that farmers do not adjust easily to acreage devoted towards sunflower production given changes in the prices in the period under consideration. While the results seem to point to the fact that farmers might not be responsive to local prices, this calls for the need to consider in detail the influence of other

relevant non-price incentives that might be posing constraints on increasing area under sunflower production in South Africa.

Overall, the coefficient of adjustment is 0.2718. The coefficient estimates time taken to adjust from the actual acreage level to the desired acreage level. The coefficient is low suggesting that farmers' adjustment to desired acreage for sunflower is rather slow. Within a period of one year, farmers make an adjustment in sunflower acreage by 27%. Characteristically, adjustment to the desired level is possible but may be imperfect due to physical and institutional limitations, fixed capital, etc., and could explain why adjustment is not instant in some contexts. In addition, the results generally show higher long-run elasticities relative to short-run elasticities, suggesting that over time, farmers are responsive to price and non-price changes. In the short-run, most or all factors of production are fixed while, as time passes through the medium- to long-run, more of these or all factors of production can change (Nerlove, 1958), thus giving farmers more time to make changes and devote more acreage to sunflower production, especially when they feel more certain that price changes are stable (Tenaye 2020).

The results above suggest the existence of a number of factors or constraints limiting farmers to achieving the desired acreage put to sunflower production in South Africa. These factors could be technological, institutional (Abdikoğlu and Unakıtan 2017). The 1996 deregulations in the agriculture sector also affected the oil industry through exposure to international forces, hence bringing with them challenges on farmers. Specifically, the sunflower sector became characterised by a deregulated market with uninformed producers no longer protected by the Marketing Boards (GRAINSA 2007). Hence, farmers might not have been responsive in adjusting area under sunflower production as they would to adjust to changes that could have been happening on the international space. This could also explain the overall low adjustment coefficient observed in the study.

### **Conclusion and recommendations**

The main aim of the paper was to determine the supply response of sunflower in South Africa through estimating the acreage elasticities. The specific objective was to identify the influence of price and non-price incentives on acreage devoted to sunflower during the period 1947 to 2016, modelled through the Nerlovian partial adjustment model. The data was tested for stationarity at levels, with differencing done where relevant at first level. Diagnostic tests (heteroscedasticity, Ramsey RESET and the Jarque-Bera) were done to check the validity of

the model used. The supply response model was found to be adequate for the study after satisfying these requirements.

The lower (close to zero) short- and long-run elasticities suggest that sunflower farmers were generally responsive to output prices, implying that the price factor is a tool that can be potentially used to influence the decision-making of farmers as to acreage they allocate towards sunflower production. The estimated price elasticities, though not high, is an indication that there exists some scope for using an appropriate pricing policy to influence supply. The agricultural pricing policy should be viewed as a comprehensive package, which moves beyond prices per se, and should be extended to include investment in rural infrastructure, agricultural services like seasonal weather forecasting, and supportive policy environment. While sunflower prices follow international prices, it may be necessary to give substantial non-price support to enable farmers to respond with relative ease to any price signal. The weak elasticity estimates also point towards existence of other non-price factors that need some consideration when supporting the sunflower farmers.

Moreover, a lower coefficient of adjustment observed imply that farmers' adjustment to desired acreage for sunflower in South Africa is rather slow, which could be attributed to physical, technical, institutional, as well as resource limitations. As such, there is a need for a better understanding of the entire sunflower value chain within the context of changing local and international trends. Other issues of consideration include provision of subsidies to sunflower farmers to allow them to use improved technologies, train farmers on how to use new technologies, and stabilize prices so that smallholder farmers can easily make area allocation decisions for sunflower. There is also a need for information on markets for sunflower disseminated to the growers.

Increased research and development efforts in development of new, high yielding sunflower cultivars could also make the crop more attractive for farmers to produce. The fact that the country is currently importing sunflower presents an opportunity for increased local production. With the right support and incentives, the sunflower crop presents an opportunity for smallholder farmers, either as new entrants into the industry or for those who may be currently involved to receive better support to increase sunflower production. This could be in form of tax and other fee rebates for farmers to reduce cost of production, as well as other transaction costs. In addition, the state could consider increasing import duties to ban edible oils and fats to reduce importation, while encouraging oil processors to buy domestic oil seeds

from local farmers. It is also important to ensure that farmers are capacitated and informed on sunflower production through strengthened extension services that enhance knowledge and technology transfer.

Policy instruments and reforms to enhance agricultural growth in South Africa, sunflower included, could be aided by continuously uncovering and evaluating a new generation of empirical knowledge of the price and non-price factors in given contexts. Therefore, there is a need to focus not only on the competitiveness of sunflowers relative to other cash crops, but also the competitiveness of the complete value chain relative to the major exporting countries. This would lead to evidence-based interventions that enhance sunflower production in the country and thus reduce South Africa's dependency on imports, as well as sustaining the sunflower industry to meet the demands of the growing population.

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