MEASURING THE SUPPLY RESPONSE FUNCTION OF TOBACCO IN ZIMBABWE

by

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Abstract

This paper presents an estimate of the price elasticity of supply for tobacco output in Zimbabwe using an adapted Nerlovian model. The results indicate a short-run elasticity of +0.34 and a long-run elasticity of +0.81, suggesting that tobacco farmers are highly unresponsive to price changes. These estimates are similar to those obtained for tobacco in supply response studies conducted in other developing African countries.

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1. INTRODUCTION

The tobacco control literature is unanimous about the detrimental effects of smoking. For example, the World Bank (1999) notes that by 2030, tobacco will account for approximately 10 million deaths per year. This will make it the single biggest cause of death worldwide. Solutions to the epidemic have generally focussed on reducing the demand for tobacco products. It has been shown that the most effective way to reduce demand is through price increases on cigarettes. This is achieved by increasing the tax rate on cigarettes, which has the further advantage of generating additional revenue for government (World Bank, 1999).

However, very little attention has been paid to the effects that these measures will have on the supply side, despite the fact that microeconomic theory predicts that a reduction in demand will lead to a lower equilibrium price for a given level of tobacco output. The difficulty with many demand side approaches is that they ignore their impact on the farmers whose livelihoods depend on tobacco. Tobacco is of primary importance to the Zimbabwean economy, making it worthwhile to investigate the nature of tobacco farmers' production decisions. Whilst a handful of studies have analysed the supply elasticity of tobacco in Nigeria, Malawi and Tanzania (Askari and Cummings, 1977; Mshomba, 1989), very few similar studies have been conducted in Zimbabwe.

The objective of this paper is to estimate the supply response of the Zimbabwean tobacco sector. Specifically, the study covers the period 1938 to 2000, and estimates the supply elasticities of tobacco using an adapted Nerlovian model. The research was enabled by reliable and current data that was available from the Zimbabwe Tobacco Association, giving the opportunity to quantify Zimbabwe tobacco growers' supply response in reaction to changes in the price of tobacco. A second objective of this paper is to develop a framework upon which further investigations of the tobacco industry can be based. For example, the international tobacco industry is negatively affected by the recent anti-tobacco legislation in the United States, raising the question of economic development in economies that are entirely dependent on the production of tobacco. The intention of this continued research will be to evaluate possible policy interventions. It will also enable an analysis of the effects of Zimbabwe's current political disturbances on the tobacco supply response to be conducted once sufficient data is available.

2. THE ZIMBABWEAN AGRICULTURAL SECTOR

The agricultural sector plays a central role in Zimbabwe's economy, accounting for almost 10 percent of gross domestic product and 44 percent of export earnings. In addition, agriculture is the largest employer in Zimbabwe's economy, with large-scale commercial farms employing 29 percent of the total formal-sector work force. Given the goals of ensuring food security, increasing export earnings and raising the standards of living in rural areas, the agricultural sector is crucial to sustained growth and development in Zimbabwe (Mudhara *et al*, 1997). Of all the agricultural commodities produced in Zimbabwe, tobacco contributes by far the greatest proportion to the total value of agricultural output (Commercial Farmers Union, 2001).

Zimbabwe is one of the top three producers of high-quality flue-cured virginia leaf tobacco, along with the United States and Brazil. Approximately 3 percent of arable land in Zimbabwe is under tobacco. Due to tobacco production being labour intensive, it accounts for a third of people employed in the agricultural sector. This makes tobacco the single largest employer of labour in the Zimbabwean economy (Zimbabwe Tobacco Association, 2001).

Tobacco is also Zimbabwe's most important contributor to foreign exchange earnings, generating almost half of the country's foreign currency (Zimbabwe Tobacco Association, 2001). In addition to this, tobacco accounts for more than a quarter of total exports from the country. Indeed, Zimbabwe is the world's second largest exporter of flue-cured tobacco after Brazil. The importance of tobacco to the Zimbabwean economy is further illustrated by the fact that it contributed 8.2 percent to gross domestic product in 2000.

3. RECENT DEVELOPMENTS IN THE TOBACCO SECTOR

Zimbabwe has a long history of political instability, a factor known to have a negative impact on agricultural production (Mamingi, 1997). Figure 1 shows the total volume of tobacco produced in Zimbabwe for the period 1938-2000. Yield has shown a relatively steady increase since 1938. However, the structural breaks that occur in output are attributable to a combination of political instability and unfavourable weather patterns. Figure 1 shows how the tobacco crop increased sharply from 1991 to 1993 after displaying moderate growth since 1982. In the 1990's total output was about a third higher than in the 1970's and 1980's. This dramatic increase was due to farmers' increased confidence in the Zimbabwean economy following government's agreement to implement the World Bank structural adjustment programme. As previously stated, weather patterns also exert a significant influence on agricultural production. These irregular weather patterns negatively affect agricultural output by interfering with the harvesting, planting or growth of crops (Mamingi, 1997). The past decade has been characterised by both severe drought and floods. Lower than average rainfall was experienced between 1990 and 1995, which caused the fall in tobacco output between 1994 and 1995 (Commercial Farmers Union, 2001). Heavy rains were experienced in the 1998 and 1999 season, with severe flooding occurring in 2000.

In 1997 Mugabe announced a controversial programme of land redistribution, throwing the Zimbabwean economy into disarray once more. Approximately 1500 white-owned commercial farms, comprising almost half of Zimbabwe's total commercial farmland, were designated to be seized without compensation and divided amongst landless blacks. By April 2001 more than 1 700 farms had been invaded and occupied by supporters of Mr Mugabe, and more than 70 percent of all farms, about 2800 in total, had been listed by the government for compulsory acquisition. Squatters have forcibly prevented farmers from planting crops, causing many farms to go out of business. A total of 260 tobacco producing farms had been occupied by July 2001 and become non-operational, resulting in a 10 000 hectare reduction in area planted to tobacco (Zimbabwe Tobacco Association, 2001). Only time will tell what the impact on agricultural output of the recent economic and political crises associated with the farm occupations will be.

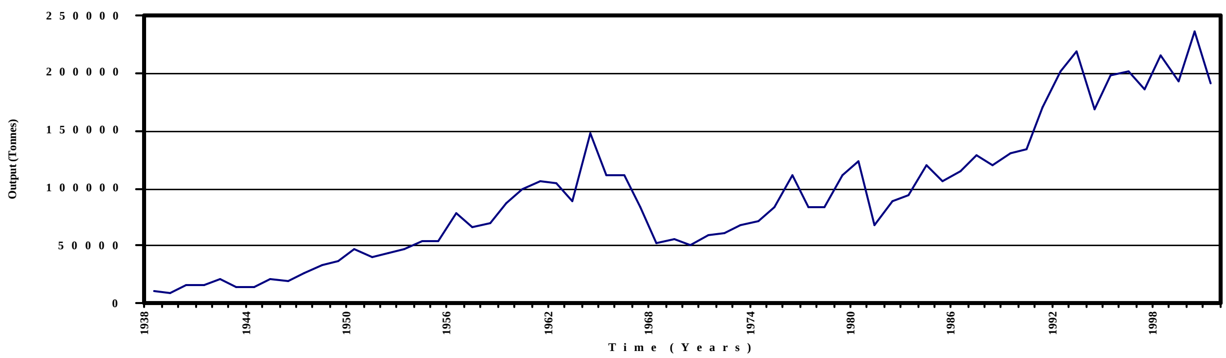

Figure 1. Total Zimbabwean Tobacco Output from 1938-2000
(Source: Zimbabwe Tobacco Association, 2001)

Figure 2 shows Zimbabwean tobacco price data for the 1938 to 2000 period. The prices are expressed in real terms and were deflated using the Zimbabwean consumer price index. The base year of the consumer price index series is 1990. There is a marked decrease in real tobacco price between 1946 and 1970 when the price dropped from 8.4 Zimbabwe cents per kilogram to 2.6 cents per kilogram. Since 1971, the tobacco price has displayed an upward trend, with a peak of 9.4 Zimbabwe cents per kilogram being achieved in 1991. Tobacco prices have been extremely volatile since 1986, partly due to variations in the quality of the tobacco produced.

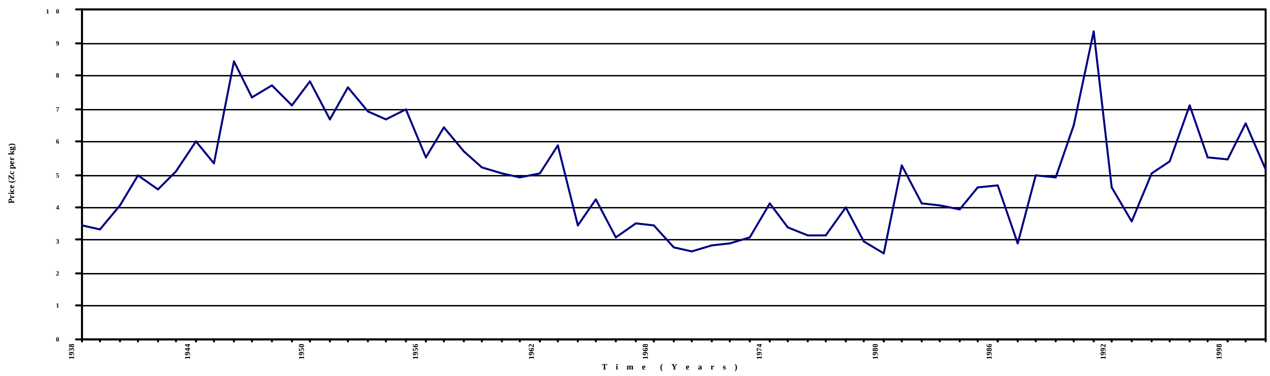

Figure 2. Zimbabwean Tobacco Price from 1938-2000 (Real Zc's/kg)
(Source: Zimbabwe Tobacco Association, 2001)

4. THE NERLOVIAN MODEL

Of all the econometric models used to estimate agricultural supply response, the Nerlovian model is considered one of the most influential and successful, judged by the large number of studies which utilise this approach (Braulke, 1982). The Nerlovian model is a dynamic model, stating that output is a function of expected price, output (area) adjustment, and some exogenous variables. According to Gujarati (1995), a model is described as dynamic if the time path of the dependent variable is explained by its previous values. The reduced form of the Nerlovian model is an autoregressive model because it includes lagged values of the dependent variable (output) among its explanatory variables. The simplest form of the Nerlovian model for an annual crop consists of the following three equations (Askari and Cummings, 1977):

1. $A^*_t = a_0 + a_1P^*_t + a_2Z_t + u_t$ (1)
2. $P^*_t = P^*_{t-1} + ß(P_{t-1} - P^*_{t-1})$ (2)
3. $A_t = A_{t-1} + ?(A^*_t - A_{t-1})$ (3)

where A_t = actual area under cultivation at time t,
A^*_t = desired area under cultivation at time t,
P_t = actual price at time t,
P^*_t = expected price at time t,
Z_t = other observed, exogenous factors affecting supply at time t,
and ß and ? are termed the expectation and adjustment coefficients respectively.

In order to estimate the supply response using the Nerlovian model, it is necessary to eliminate the unobservable variables associated with expected price and desired output from equations (1) to (3)

(Braulke, 1982). By eliminating these variables, the estimating or "reduced form" Nerlovian equation is achieved. The reduced form is given by:

$$A_t = b_0 + b_1 P_{t-1} + b_2 A_{t-1} + b_3 A_{t-2} + b_4 Z_t + b_5 Z_{t-1} + v_t \tag{4}$$

Where: b_o = a_0ß?,
b_1 = a_1ß?,
b_2 = (1-ß) + (1-?),
b_3 = -(1-ß)(1-?),
b_4 = ?a_2,
b_5 = -?a_2(1-ß),
v_t = ?(u_t – (1-ß) u_{t-1})

The short-run price elasticity is calculated from:

$$e = b_1 \frac{\overline{P}}{\overline{A}}$$

The long-run price elasticity is calculated from (Braulke, 1982):

$$e = \frac{b_1}{1 - b_2 - b_3} \cdot \frac{\overline{P}}{\overline{A}}$$

Where $\overline{P}$ *and* $\overline{A}$ *are the historical mean of prices and output respectively.*

4.1 SPECIFYING PRICE

One of the initial decisions confronting the researcher is how to measure output price. In the original model, Nerlove phrases actual prices in terms of those currently obtainable in the market, whilst expected prices are described in terms of past market prices (Askari and Cummings, 1977). Thus Nerlove hypothesises that price expectations are formed as follows:

$P^*_t = P^*_{t-1} + ß(P_{t-1} – P^*_{t-1})$

such that ß, the coefficient of expectation, is 0<ß=1. This hypothesis is known as the adaptive expectations model, and states that economic agents revise their price expectations each period by a fraction ß of the difference between the previous periods actual price and the previous periods expected price (Gujarati, 1995). Thus individuals are assumed to take past price experience into account when forming their price expectations.

One of the most important factors relating to the output price specification is in choosing the relevant deflator (Mamingi, 1997). The output price may be deflated by the consumer price index, the producer price index, or an index of the prices of competitive crops. Using the nominal output price does not make economic sense if inflation is high, since farmers will be interested in the actual purchasing power of their money and as a result will respond to changes in *real* output prices rather than changes in nominal prices. This paper uses the consumer price index as deflator.

4.2 SPECIFYING QUANTITY

There is a great deal of disagreement in the literature on what the correct measure of output is. The three choices for measuring output are the acreage under cultivation, production or yield per unit area, and total production in terms of weight or tonnage produced (Mshomba, 1989).

The best measure of output appears to be the use of the actual produce weight because it acknowledges that farmers may respond to price incentives by using either more intensive *or* more extensive farming techniques. An additional factor in favour of the use of this particular measure is that data on tonnage produced is readily available.

4.3 SPECIFYING Z

The variable Z is included in the model to capture the effect of any relevant non-market factor affecting output (Askari and Cummings, 1977). The idea of shifts in production due to technical reasons is well understood in the production economics literature, for example see Flinn and Musgrave (1967) who raise it in the context of shifts in production due to water stress and Ritson (1980) who discusses shifts in agricultural supply due to technological advancements. A survey of the relevant literature shows that the two most common shift variables are weather, usually measured by rainfall, and a time trend (Mamingi, 1997).

A common error in many Nerlovian models is that the rainfall variable is included in a linear form (Mamingi, 1997). The linear specification is incorrect since eventually there can be too much rain, or flooding, and this will result in *reductions* to, rather than increases in, output. Thus rainfall could be included as a dummy variable, with periods of optimal rainfall taking a value of 1, and periods of above or below average rainfall being allocated a value of 0. According to Askari and Cummings (1977), the inclusion of a time trend variable instead of specific variables is justified if there is a lack of availability of data or if there is multicollinearity among variables. In this case, the time trend variable would act as a proxy for improvements in technology and other farming methods over time. However, Mamingi (1997) warns that omitted variables should only be captured by the use of a time trend variable as a last resort, since the whole point of the model is to determine the impact of *specific* variables.

5. ESTIMATING THE TOBACCO SUPPLY RESPONSE

A modified form of the Nerlovian model is used in this study, to prevent various problems that arise from the statistical estimation of the original Nerlovian model. Alterations of this type are well documented in the agricultural supply response literature, for example see Sharma (1992) who uses a partial adjustment model only, thereby excluding the price expectation process, and Askari and Cummings (1977) for a list of other studies that impose restrictions on the traditional Nerlovian model.

The estimation of the Nerlovian model may result in residuals that violate the assumption of normality of the error terms. This is a simplifying assumption of the classical normal linear regression model, and must be satisfied for the method of ordinary least squares to be the best linear unbiased estimator (BLUE). To ensure normality of the residuals, the estimating equation used in this study is expressed in logarithmic form. The transformation is justified because it ensures that the errors are both homoskedastic and normally distributed (Maddala, 2001). An additional advantage of using the logarithmic form is that the coefficient of the price variable can be directly interpreted as the short-run supply elasticity.

Four shift variables that affect tobacco output are included in the model. The first is a dummy variable for annual average rainfall. Tobacco requires rainfall of 600 to 800 mm/year. Annual average rainfall of more than 800 mm/year has a negative impact on tobacco output since it interferes with the growth, harvesting and drying of the tobacco. In addition, tobacco requires a large amount of sunlight, which may not be available if annual rainfall exceeds 800 millimetres. In years of drought, where annual average rainfall of less than 450 millimetres is recorded, tobacco output may also be negatively affected (Zimbabwe Tobacco Association, 2001). The dummy variable takes the value of 0 in years with moderate rainfall of between 450 to 800 mm/year and a value of 1 otherwise. Due to the fact that tobacco is grown between October to March, and yield is negatively affected by heavy rains early in the season, the rainfall dummy variable is lagged by one period. This means, for example, that the 1998 crop, which includes tobacco grown during both October to December 1997 and from January to March 1998, is affected by the 1997 rains.

The second shift variable is a dummy variable to capture the effect of sales quotas imposed on Zimbabwean tobacco farmers during the years 1967-1973, 1976-1977, and 1981-1983 (Townsend and Thirtle, 1997). The quota dummy variable takes the value of 1 in years in which a sales quota applies, and 0 otherwise. The third and fourth shift variables are a simple time trend and a quadratic time trend variable respectively. The time trend variables are frequently included in agricultural supply response studies to capture the effect of technology changes, for example see Sharma (1997) and Pandey, Piggott and MacAulay (1982), but they also capture any unspecified non-technological effects.

Data on the Zimbabwean consumer price index for the period 1938 to 2000 were obtained and converted into a common series with a base year of 1990. The tobacco prices were then deflated using this consumer price index.

The supply response equation is expressed as:

$$LOUTPUT_t = b_0 + b_1 LREALPRICE_{t-1} + b_2 LOUTPUT_{t-1} + b_3 LOUTPUT_{t-2} + b_4 QUOTA + b_5 RAIN_{t-1} + b_6 TIME + b_7 TIME2 + U_t$$

Where:
$LOUTPUT_t$ = log of total tobacco output produced in year t, and measured in tonnes;
$LREALPRICE_{t-1}$ = log of the real tobacco price, expressed in Zimbabwe cents per kilogram;
$LOUTPUT_{t-n}$ = log of total tobacco output lagged by n years;
QUOTA = dummy variable for years with a sales quota (1 for the years 1967-1973, 1976- 1977, and 1981-1983, and 0 in all other years);
$RAIN_{t-1}$ = dummy variable for rainfall (1 for years with rainfall below 450 millimetres or above 800 millimetres, 0 otherwise);
TIME = simple time trend (t=0 for 1938 to t=62 for 2000);
TIME2 = quadratic time trend (t=0 for 1938 to t=3844 for 2000);
Ut = error term.
The short-run supply elasticity is measured by b_1, and the long-run supply elasticity is measured by $b_1/(1-b_2-b_3)$, as derived in Section 4.3.

5.1 RESULTS OF THE SUPPLY RESPONSE EQUATION

5.1.1 Importance and significance of variables

The logarithmic form of the Nerlovian model was estimated in E-views using ordinary least squares. The regression results for the period from 1938 to 2000 are presented in Table 1. The signs of all the coefficients are as predicted by theory. The results show that price lagged one period, output lagged both one and two periods, and the simple time trend all exert a positive influence on tobacco production. The sales quota dummy, rainfall dummy and quadratic time trend variable exert a negative influence on tobacco output. The negative coefficient of the quadratic time trend variable implies that unspecified effects are causing tobacco output to increase, although at a decreasing rate. These variables together explain about 96 percent of the variation in Zimbabwean tobacco output.

The coefficient of the real price variable is positive and significant at the 1 percent level indicating that a price increase will be followed by an increase in output in the subsequent period. Output lagged once is also positive and significant at the 1 percent level, suggesting that an increase in output in one period will be followed by increased output in the next period. This is due to farmers' commitment to covering their fixed capital costs .

The coefficient of the sales quota dummy variable is negative and significant at the 5 percent level. This finding is to be expected, and indicates that farmers decrease tobacco output by 16 percent following the imposition of a sales quota. Tobacco output is also reduced when annual rainfall is below 450 millimetres or above 800 millimetres. This is confirmed by the negative coefficient of the rainfall dummy variable, which is significant at the 10 percent level. The implication is that rainfall plays an important role in determining tobacco output in Zimbabwe, with both too much and too little rain causing reductions in tobacco output.

Unquantified impacts, for example technology improvements and increases in efficiency, are captured by the simple time trend and quadratic time trend variables. The fact that the coefficient on TIME is positive whilst on TIME2 it is negative suggests that the impact of these unquantified factors is increasing but at a decreasing rate. The coefficient of the TIME variable implies that technological change is causing a shift in the tobacco supply function of 4.5 percent per year. The coefficients of both the simple time trend and quadratic time trend variables are significant at the 1 percent level.

Table 1. Regression Results for the Tobacco Supply Response from 1938 to 2000

Dependent variable: LOUTPUT		
Independent variables	Coefficient	t-value
CONSTANT	3.45724	4.83996*
LREALPRICE(-1)	0.34354	3.83444*
LOUTPUT(-1)	0.43465	3.89031*
LOUTPUT(-2)	0.13943	1.30825
QUOTA	-0.16326	-2.23212**
RAIN	-0.09977	-1.87948***
TIME	0.04453	4.26354*
TIME2	-0.00042	-3.53856*
Adjusted R^2 = 0.9564	Durbin-Watson = 1.8121	Observations = 61
* indicates significance at the 1 percent level.		
** indicates significance at the 5 percent level.		
*** indicates significance at the 10 percent level.		

5.1.2 Diagnostic Tests on the Supply Response Model

The computed Jarque-Bera statistic of 0.02 and associated p-value of 0.99 confirms that the residuals are normally distributed. This finding is important because it ensures the validity of the *t* and *F* tests. The Durbin-Watson statistic of 1.81 does not allow a decision to be made regarding the presence of autocorrelation among the residuals. Based on these results, the model appears to be adequate in terms of its specification.

5.1.3 Estimated elasticities

Table 2. Tobacco Supply Elasticities for Zimbabwe from 1938 to 2000

Short-run elasticity	0.34
Long-run elasticity	0.81

Both the short-run and the long-run elasticities are positive and fall in the inelastic range, implying that Zimbabwe tobacco farmers are relatively unresponsive to price changes. Specifically, a 10 percent increase in the real price of tobacco will lead to an increase in tobacco output of 3.4 percent in the short-run and 8.1 percent in the long run. Note how the short-run supply elasticity is smaller than the long-run supply elasticity. This is an important characteristic of individual crop supply elasticities and occurs due to the fact that in the short-run some factors of production are fixed, whilst in the long-run all factors are variable.

The short-run elasticity of 0.34 obtained in this study is comparable to Townsend and Thirtle (1997), who calculated the short-run supply elasticity of tobacco in Zimbabwe to be 0.28. However, contrast the long-run elasticity of 0.81 to Townsend and Thirtle's long-run elasticity of 1.36.

The short-run elasticity is also comparable to that of 0.48 calculated for tobacco in Malawi (Adesimi in Askari and Cummings, 1977). Similarly, the long-run supply elasticity is also remarkably similar to that of 0.82 calculated for Nigerian tobacco (Adesimi in Askari and Cummings, 1977).

6 CONCLUSIONS

The objective of this paper was to estimate the supply elasticities of Zimbabwean tobacco using the Nerlovian model. Both the short-run and long-run supply elasticity fell in the inelastic range, indicating that Zimbabwean tobacco farmers are relatively unresponsive to output prices. Specifically, the short-run elasticity was 0.34 and the long-run elasticity 0.81.

This finding quantifies the extent of the domination of the tobacco industry in the Zimbabwean economy and raises interesting research issues such as the likelihood of policy intervention changing the structure of the Zimbabwean economy. The high fixed capital costs of infrastructure necessary for tobacco production is a reason why Zimbabwean tobacco farmers are so unresponsive to price. High capital costs translate into large opportunity costs associated with giving up tobacco production, thereby further entrenching the production of a harmful product even under adverse conditions. A further reason why Zimbabwean farmers find tobacco such an attractive crop is because it is 6.5 times more profitable than other alternative crops. In addition, it is non-perishable and can be stored easily, unlike many other crops (World Bank, 1999).

What emerges from this paper is that Zimbabwean tobacco farmers will keep growing tobacco, even with significant price decreases, because they perceive no other viable alternative. This clearly begs the developmental issue of how the first world can meet their objective of tobacco control whilst helping African nations such as Zimbabwe to find their feet in a global economy which does not run on tobacco.

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