

Supply Response, Risk and Institutional Change in Nigerian Agriculture

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AERC Research Paper 197
African Economic Research Consortium, Nairobi
May 2010

THIS RESEARCH STUDY was supported by a grant from the African Economic Research Consortium. The findings, opinions and recommendations are those of the author, however, and do not necessarily reflect the views of the Consortium, its individual members or the AERC Secretariat.

Published by: The African Economic Research Consortium
P.O. Box 62882 - City Square
Nairobi 00200, Kenya

Printed by: Regal Press (K) Ltd
P.O. Box 46166 - GPO
Nairobi 00100, Kenya

ISBN 9966-778-67-5

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Abstract

Nigeria is among many African countries that have engaged in agricultural liberalization since 1986 in the hope that reforms emphasizing price incentives will encourage producers to respond. Hitherto, the reforms seem to have introduced greater uncertainty into the market given increasing rates of price volatility. This study therefore models supply responses in Nigerian agriculture that include the standard arguments as well as price risk. The data come from the AGROSTAT system of the statistical division of the Food and Agriculture Organization (FAO), Federal Ministry of Agriculture statistical bulletins, Central Bank of Nigeria statistical bulletins, Federal Office of Statistics Agricultural Survey Manual and the World Bank Africa Development Indicators. The data are analysed using autoregressive distributed lag and error correction models. The results indicate that producers are more responsive not only to price but to price risk and exchange rate in the structural adjustment programme (SAP) period than in the commodity marketing board (CMB) period. Following deregulation, price risk needs to be meaningfully reduced for pulse and export crops, especially cowpea and cocoa.

Acknowledgements

I am very much obliged to the African Economic Research Consortium (AERC) for financial, material and technical assistance for this study. I appreciate the useful suggestions and comments of group AT (now group D) resource persons: Ademola Oyejide, Francis Mwega, Andy McKay, Jean-Paul Azam, Dominique Njinkeu, Gamal Ibrahim, Melvin Ayogu and Eugene Kouassi. I am also grateful to the research fellows in the group for their contribution to the improvement of this paper. However, all errors should be considered to be mine.

1. Introduction

Like the majority of countries in sub-Saharan Africa, Nigeria has been following a structural adjustment programme (SAP) since 1986. Significant progress made includes large and frequent devaluations of the nation's currency (Naira) and exchange rate liberalization, as well as tax reform and rationalization including tariffs, decontrol of agricultural prices and liberalization of marketing (Oyejide, 1990; Kwanashie et al., 1998). The rationale behind agricultural liberalization is that the biases against agriculture inherent in the protectionist policies of the commodity marketing boards (CMBs), evident in Nigeria since 1948, discourage production so that reforms introducing price incentives and efficient marketing will encourage producers to respond.

As part of the government drive towards freeing up agricultural markets, the CMBs were abolished in 1986, thus ending 36 years of market intervention. The effects of this deregulation on the producers have been profound. Notably it introduces greater uncertainty into a market that hitherto had been subject to strict controls to stabilize prices. Although increased price volatility presaged the cessation of CMBs, the present role of producers in tackling both production and price risks deserves inclusion of risk in quantitative assessment of their supply response.

This study therefore reflects on structural differences in the response of Nigerian agriculture to price and price risk in two major policy intervention periods with a view to informing the debate about deregulation, not least because the deregulation of similar schemes is going on in other countries in Africa. Previous studies of Nigerian agricultural markets have tended to model supply response based on the assumption of perfect knowledge and information about price and production (Ajakaiye, 1987; Oyejide, 1986, 1990; Oni, 1969; Abalu, 1974; Kwanashie et al., 1998). Less attention has been paid to capturing the impact of risks and uncertainty on agricultural production and supply response in Nigerian agriculture. Since the nature of market and non-market incentives is adding to risk and uncertainty in farm decisions, this study aims at modelling the production and supply response in Nigerian agriculture to include both the standard arguments and risk. Specifically the study attempts to:

- ◆ Determine whether Nigerian agricultural supply is price and price risk responsive;
- ◆ Examine the subaggregate and selected individual crop supply response of Nigerian agriculture to price and price risk; and
- ◆ Evaluate the impact of structural breaks on Nigerian agricultural supply response.

The main hypothesis is that the inclusion of risk in Nigerian agricultural supply response will not reduce farm output. The main body of the study comprises an econometric model of the agricultural markets over the period 1970 to 2003. This span

of years covers the period of effective CMBs (1970–1985) and the SAP era (1986–2003). Modelling is via Nerlovian dynamic expectation and Just (1974) risk models as embodied in the theory of cointegration. The models are estimated for aggregate, subaggregate and individual crop data. The results permit estimates of both short-run and long-run supply elasticities in the agricultural markets.

The paper proceeds as follows: Section 2 provides a brief overview of the Nigerian agricultural sector and an outline of major policy changes during CMB and SAP stewardship so as to establish the institutional backdrop for the theoretical discussion of Section 3 in which the economic model is formulated. Section 4 applies time series data to the model to quantify relationships and behaviour using appropriate techniques. Finally, Section 5 presents the implications of the results.

2. An overview of Nigeria's agricultural sector and market policies

Before the crude oil era of the 1970s, Nigeria's agriculture sector contributed significantly to the country's economy. During this period (1961–1970), agriculture accounted for an average of 56.6% of the nation's foreign exchange and more than half of the gross domestic product (GDP) (Idachaba, 1994; CBN, 2000). Given this substantial contribution, agriculture to a large extent dictated the pace of growth and development of Nigeria's economy. There is consensus that the sector was a source of economic stability during this period because of its positive contributions to foreign exchange earnings, rural employment and urban development (Helleiner, 1966; Adamu, 1970; Oyejide, 1990; Kwanashie et al., 1998). The sector was also the main source of income for farmers.

Favourable world markets for the main cash crops (cocoa, rubber, groundnut, palm oil and coffee) activated local production and marketing, which helped to maintain a large measure of rural-urban equilibrium and provided the bulk of the capital Nigeria needed for development. The main capital contributions were taxes imposed on export crops and the accumulated surpluses of the state-run marketing boards. Perhaps more important to national development was the contribution of the sector to the supply of foreign exchange needed for acquisition of capital goods for industrial and general infrastructure development. The sector was a major source of support for Nigeria's early attempts at industrialization via provision of raw materials for processing.

The positive role of agriculture was not sustained in the 1970s and early 1980s because of the emergence of a virile petroleum sector. Thus the agricultural sector saw its share of foreign exchange earnings shrink to less than 15% annually between 1971 and 1985 (CBN, 2002) (Table 1). Other reasons for the decline – apart from the marginalization of agriculture because of the huge petroleum earnings – include unwholesome activities of the Nigerian marketing boards between 1978 and 1986, irregularity in the supply of production inputs, and unstable global and domestic prices (Evuomwan, 1996). Two major danger signals of the decline were the inability to meet the raw material needs of primary processing industries and the loss of competitive position in the production and export of the commodities.

Table 2, showing the contribution of the agricultural sector to GDP, reveals that the share has been below 50% since 1970. The sector contributed 48.6% between 1970 and 1974; the share fell to 30.3% between 1975 and 1979 but rose to 37.7% between 1980 and 1984 and then to 40.9% during 2000–2002.

Table 1: Contribution of Nigeria's agricultural sector to foreign exchange (1970–2002)

Period average Agricultural (%)	Total export (Million Naira)	Agricultural export (Million Naira)	export
1970–1974	2,326.4	297.6	12.8
1975–1979	7,193.1	410.0	5.7
1980–1984	8,323.0	622.47	7.47
1985–1989	5,691.0	8,314.0	5.6
1990–1993	163,949.5	3,086.6	1.8
1994–1998	4,459,783.5	163,372.0	8.6
1999–2002	1,292,052.6	20,695.5	1.6

Source: CBN *Statistical Bulletin*.

Table 2: Contribution of Nigeria's agricultural sector to GDP 1970–2003

Period (%)	Annual total GDP (N billion)	Share of agric in GDP
1970–1974	58.2	48.6
1975–1979	73.7	30.3
1980–1984	68.6	37.7
1985–1989	74.4	41.3
1990–1994	96.7	38.3
1995–1999	109.9	47.3
2000–2003	123.0	40.9

Source: CBN *Statistical Bulletin* and various bulletins.

In terms of policy intervention, agricultural marketing in Nigeria has passed through two major policy regimes – the CMB and the SAP. A third would have been the emerging commodity exchange and futures market, but the exchange is still in its infancy. At present its activities remain at a low ebb and greater awareness is needed for it to be fully operational. Hence this section reviews CMB and SAP.

After the Second World War in 1947, the Nigeria Produce Marketing Board (NPMB) was established as the sole buyer of all commodities produced for export. The board determined the purchase prices under the approval of the central government. However, the Nigerian Produce Marketing Company Limited incorporated in the United Kingdom handled overseas marketing.

In 1954, regional marketing boards were established to handle marketing in various regions, while the Nigerian Central Marketing Board was set up to act as an agent of the regional marketing boards, handle export sales and shipping of produce, establish and control quality and grades, and purchase from regional boards. In 1957/58, the NPMB and Nigerian Produce Marketing Company Limited registered in Lagos became effective. Overseas buyers could then purchase commodities on either c.i.f. or f.o.b. basis. The London office was closed in 1962/63 and all sales were conducted from Lagos on a net price basis. The regional marketing boards with their statutory powers and duties became responsible for the marketing of major export crops. They appointed licensed buying agents, fixed prices and established a crop stabilization fund from their reserve funds.

In 1973, following a period of low world market prices for major primary commodities – cocoa, coffee, palm kernel, rubber and groundnut – the federal government introduced legislation providing for central control over the pricing and the financing mechanism of export crops. A technical committee on producer prices was established to advise the Head of State.

When 19 states were created in 1976, the government did not believe that it was desirable to create a marketing board for each because of expensive overheads, wastage and duplication of efforts. Hence, the existing marketing boards were reorganized into a price fixing authority and seven commodity boards, which operated on a nationwide basis and cut across state boundaries. Unlike the marketing boards, whose major objective was to market Nigeria's agricultural products overseas, the main objective of the 1976 reorganized commodity boards was to encourage the production and organize the marketing of major agricultural commodities for local consumption and local processing. The emphasis was on rendering maximum benefit to the farmers and satisfying home demand, including the need to process the country's raw materials before export. The seven commodity boards were the cocoa board, which is also responsible for coffee; the groundnut board, which also looked after soybean, beniseed, sheabutter and ginger; the cotton board, which also deals with kenaf and similar fibres; the palm produce board, which deals with palm oil, palm kernel and copra; the rubber board; the grain board, which handles all food grains; and the root crops board, which deals with tubers and root crops. The reformed boards covered the key food crops as well as traditional export crops. Each of the boards provided a guaranteed minimum price at which the farmers sold to the boards. Farmers and plantation owners were free to sell to local processors, however, without going through relevant boards.

With respect to mode of operation, the boards appointed licensed buying agents (LBA) – companies, individuals or cooperative societies – to purchase, bag, store, grade and transport commodities to the boards' port stores. The respective state ministry of agriculture and natural resources produce department inspects, grades and certifies the produce before it leaves the LBA stores. The boards publish annually the list of LBAs, their functions, responsibilities, grades, transport cost, handling instructions, annual price and buying allowance payable to the LBAs.

In spite of the laudable aim of these boards, it has been found that none of them satisfied the objectives for which it was set up. The weight of academic and policy maker opinions (Olatunbosun and Olayide, 1972; Olayide et al., 1974; Edache, 1994; Idachaba, 1994; Oyinloye, 1999) is on the fact that the marketing boards have not succeeded in the primary objectives of stabilizing either the price of commodities or the income of food and export crop producers. The main problems of the marketing boards were found to be shortage of skilled management, scarcity of data on commodity production, inadequate material funding, bureaucratic sludge and low prices paid to farmers. The greatest problem is that the marketing board concept constituted a disincentive to effective pricing of agricultural commodities. Farm incomes were low and could hardly support reasonable expansion of production in terms of area and yield.

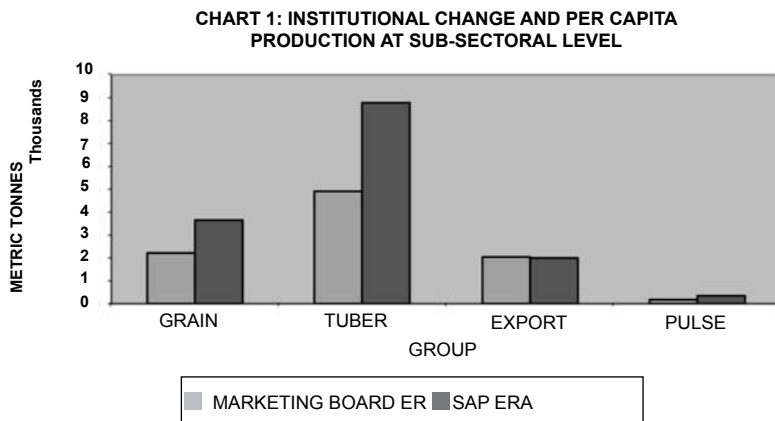
The introduction of the SAP in 1986 ushered in the dissolution of all the marketing boards and the introduction of a free market pricing policy. Many people became registered as exporters with each of the state ministries of agriculture and the Nigerian

Export Promotion Council. The exporter selects buying agents and registers them with the appropriate ministry of agriculture produce department. Once done, they become LBAs to the exporters. In the new arrangement, government has no business setting prices of agricultural commodities. Interaction among exporters, their LBAs and producers determines prices of export crops, while domestic market demand and supply determine the price of food and fibre crops.

The agricultural sector grew at a rapid rate following the introduction of the SAP and the liberalization of both internal and external markets. Producer prices that were formerly fixed at low level by the technical department of the marketing board were now purely market determined. The free market pricing policy led to increased agricultural production as well as nominal income of the farmers.

At individual crop level, economists (Oyejide, 1990; Ajakaiye, 1987; Kwanashie et al., 1998) agree that SAP has led to increase in production of agricultural commodities. For all the commodity aggregates considered in the SAP era, an increase in per capita production is recorded when compared with production during the CMB era. The greatest increase was observed in root and tuber crops (Figure 1).

Figure 1: Institutional change and per capita production at subsector level



The leading role of Nigeria in cassava production is evident from Figure 2. Next to cassava was yam, which recorded an increase in average production from about seven million tonnes in the marketing board era to 20,000 metric tonnes in the post-marketing board era. Production of other root and tuber crops, such as sweet potatoes and cocoyam, is still at a low ebb, however.

Similarly for grains, a sizeable increase in production was observed with the change from the market stabilization policy of the CMB to the liberalization policy of the SAP era. The average production during the marketing board era was about one million tonnes, but by the end of 2003, the average production during post-marketing board era stood at about 5.5 million tonnes. The greatest change is observed for maize, followed by sorghum and rice, respectively (Figure 3). Although wheat is a major ingredient in bread, its production is still insignificant when compared with its demand. Government is experimenting with the use of cassava as an alternative bread flour given the surge in its production in the post-marketing board era.

Figure 2: Institutional change and production of root and tuber crops

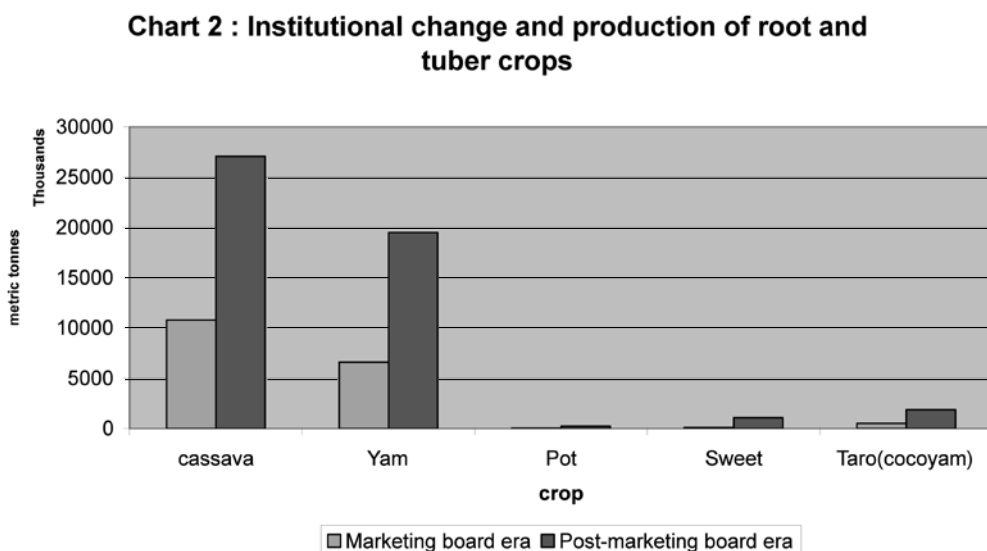
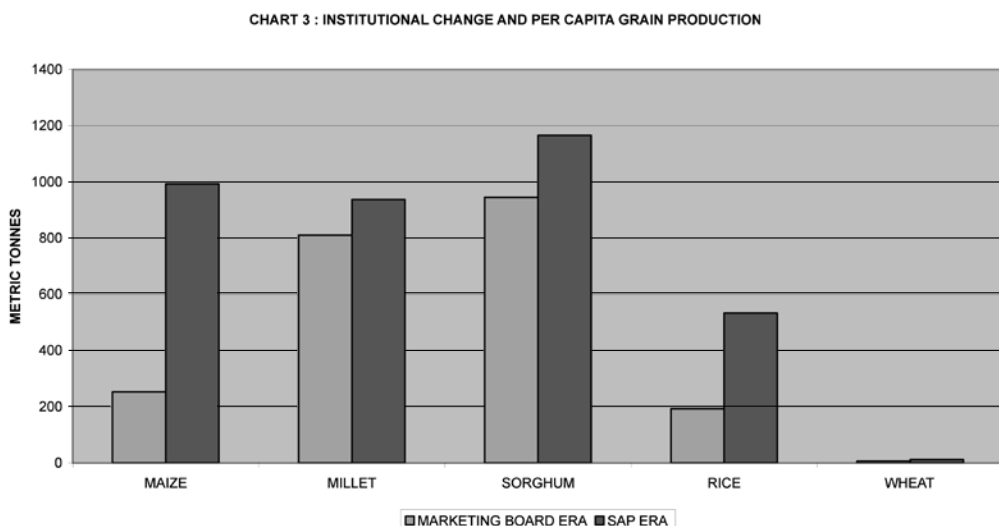
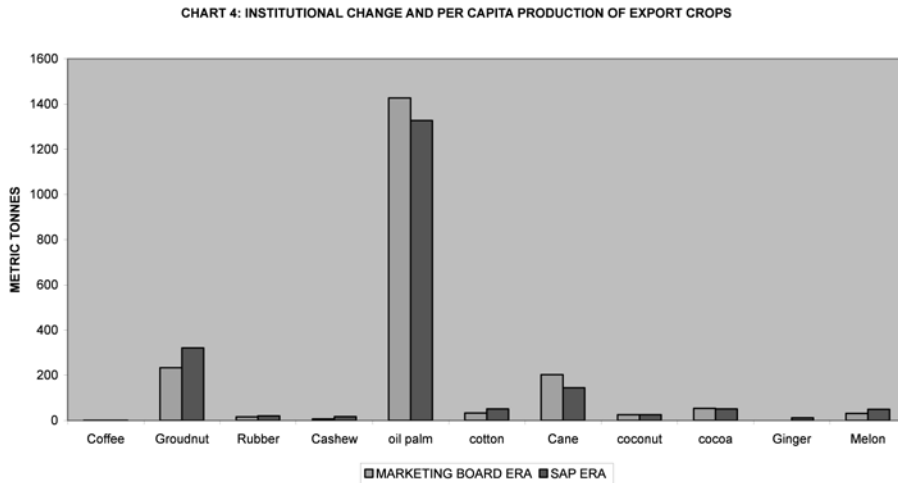


Figure 3: Institutional change and per capita grain production



Export crop production in the aggregate showed a rising trend. Both during and since the marketing board era, the production of oil palm is the highest. One could say that this will return to its former position in global export of palm oil products, although this is still far from reality as local consumption greatly exceeds production. The production of cane in the aggregate was the same in both marketing and post-marketing board eras, while the production of cotton, cocoa, cashew and rubber changed only slightly (Figure 4).

Figure 4: Institutional change and per capita production of export crops

Given increased production, the expectation of policy makers is that market liberalization would make prices stable since the opening up of markets would mean that a greater number of consumers and producers would adjust their demand and supply to shocks, thereby reducing adjustment in prices. A greater matter for policy consideration is that the trend does not signal increased stability, as will be shown later. Two effects need to be considered here:

- ◆ The focus of production will shift from crops with a high level of protection to those whose costs are relatively low. If production is unstable in the latter, the overall variability in production will increase and vice versa.
- ◆ As government removes price supports with liberalization, it seems the private sector has not fully replaced the role of government. The resultant effect of price instability will continue as long as production does not meet demand. This may be the greatest problem the emerging commodity exchange in Nigeria faces if market instability is not sufficiently reduced.

The new arrangement under SAP has considerably increased the private sector's role in agricultural product marketing. More people with little or no technical know-how about quality control have entered the marketing arena, however, while production is still largely in the hands of peasant farmers who depend on fragmented landholdings and low input/output technology. Another problem of the SAP in agriculture is the unstable demand and prices of agricultural products. The pricing of the crops is set by demand on both domestic and global markets. The global markets, coupled with economic inefficiencies of agricultural commodity producers, increase producer risks. During the stabilization policy era they were price takers, but they now have to contend with price risks as well as production uncertainty. This study attempts to model their supply response by incorporating a risk variable.

3. Conceptualizing the Nigerian agricultural market

By documenting the evolution of Nigerian agricultural market policy, the preceding section highlighted the key instruments of regulation. Here attention is focused on the impact of the regulatory mechanisms on the supply behaviour of producers. During the marketing board era, when prices were fixed and technology subsidized, the traditional production function approach took prices and technology as given (without risk), in which case profit maximization would be the appropriate expression of producer behaviour. In the SAP period, prices are determined by demand and supply relationships in an imperfect market and technology is no longer subsidized. The need arose therefore for incorporating risk considerations (technical uncertainty and market risk) into the appraisal of supply response through estimation of expected loss. The guiding hypothesis is that inadequate treatment of risk has been a major factor accounting for the discrepancy between actual and predicted (profit maximizing) national or individual production and income in other recent studies (Kwanashie et al., 1998). Given the specific risk framework to be developed, it is hypothesized that farmers' operational decisions are more consistent with utility maximization than with profit maximization. These hypotheses are considered in modelling supply response in the context of regulatory mechanisms in Nigeria.

Creating a supply response and risk model

Supply response seeks to explain the behaviour change of producers with respect to the production, consumption and exchange decisions for a certain product or a set of products arising from changes in economic incentives. Rational price sensitivity on the part of producers would presuppose desirable responses to changes in prices. Conversely, insensitive producer behaviour is construed as insignificant or lacking output responsiveness despite notable changes in prices. Abolition of the marketing boards and liberalization of the agricultural markets are hypothesized to increase the nominal effective protection of the farmers even as the ratio of domestic price to border prices increases. Also, the removal of legislation on minimum staple food prices and various tax reforms to discourage importation of some food items aim at increasing indigenous production of the crops. The producers' intention and their actual performance can be measured by either actual production or area actually cultivated with a particular crop or aggregates. Since producers' decision behaviour could be approximated by the amount of effort they are willing to put into (or withdraw from) the production process, the size of the area worked could be a proxy for their expected output rather than the actual harvest in defining a response to economic incentives. The starting point in the

modelling is the selection of either the amount of production or the size of the cultivated area as the dependent variable. This study tried both. Given the heterogeneous nature of agricultural production, the response of different producers to market stimuli will vary quite widely. It is well known that the opportunity costs of production are not necessarily equal across all farms, thus modelling response to change in the aggregate only will tend to mask these differences. To measure the response exactly would require highly detailed disaggregated cost data that are typically unavailable. To circumvent the data problem, it is common in the empirical literature to adopt a reduced form representation in preference to a fully specified formulation. The ease and tractability of the reduced form is exemplified by the popularity of the partial adjustment adaptive expectation dynamic model developed by Nerlove (1958) in which the dependent variable is determined by lagged price, lagged dependent variable and other variables such as price of competing crops. Following Nerlovian (1958, 1979) traditions, with specific forms to be determined on the basis of a priori theoretical considerations and particular circumstances, the general supply response model can be presented as:

$$Q_t^d = \alpha_1 + \alpha_2 P_t^e + \sum \alpha_{3i} X_{it} + \varepsilon_t \quad (1)$$

where Q^d is desired level of output; P^e is a vector of expected level of prices and X_i represents the set of non-price factors; α_i 's are parameters with α_2 being the long-run coefficient (elasticity); and ε_t accounts for unobserved random factors with zero expected value. The Nerlovian models are constructed to handle two dynamic processes, adaptive expectations and partial adjustments, thus:

$$\begin{aligned} Q_t - Q_{t-1} &= \delta(Q_t^d - Q_{t-1}) + v_t \\ 0 &\leq \delta \leq 1 \end{aligned} \quad (2)$$

where δ is the partial adjustment coefficient and v_t is a random term. Specification of a model that explains how price expectations are formed based on differences between actual and past prices assumes:

$$P_t^e - P_{t-1}^e = \gamma(P_{t-1} - P_{t-1}^e) + \omega_t \quad (3)$$

where γ is the adaptive expectations coefficient and ω_t is a random term.

Assuming that producers make their planting decisions according to their knowledge about prices that prevailed immediately the preceding period, then:

$$P_t^e = P_{t-1}^e \quad (4)$$

Substituting equations 1 and 4 into 2 would eliminate the unobservable variable (Q_t^d) to yield a structure that describes dynamically a supply response model for which

parameter estimates can be obtained using either maximum likelihood procedure or least squares technique on an equation of the reduced form (Askari and Cummings, 1977; De Janvry and Sadoulet, 1995) such that:

$$\begin{aligned}
 Q_t - Q_{t-1} &= \gamma(\alpha_1 + \alpha_2 P_{t-1} + \sum \alpha_{3i} X_{it} + \varepsilon_t - Q_{t-1}) + v_t \\
 &= \gamma\alpha_1 + \gamma\alpha_2 P_{t-1} + \sum \gamma\alpha_{3i} X_{it} - \gamma Q_{t-1} + \gamma\varepsilon_t + v_t \\
 Q_t &= \beta_1 + \beta_2 P_{t-1} + \sum \beta_{3i} X_{it} + \beta_4 Q_{t-1} + \mu_t
 \end{aligned} \tag{5}$$

where,

$$\beta_1 = \alpha_1 \gamma; \beta_2 = \alpha_2 \gamma; \beta_3 = \alpha_3 \gamma; \beta_4 = 1 - \gamma; \text{ and } \mu_t = \gamma\varepsilon_t + v_t \tag{6}$$

$$\text{Hence } \alpha_1 = \beta_1 / \gamma; \alpha_2 = \beta_2 / \gamma; \gamma = 1 - \beta_4; \text{ etc}$$

Short-run and long-run elasticities could then be derived from these relations as follows. In the linear form of the equation, short-run and long-run price elasticities are given, respectively, by $\beta_2(P/Q)$ and $(\beta_2/\beta_4)(P/Q)$ where P and Q are mean values of prices and output, respectively. In the log-linear form of the equation, β_2 and (β_2/γ) would directly measure short-run and long-run price elasticities, respectively (Askari and Cummings, 1977; Berhman, 1968; Sharma, 1992; De Janvry and Sadoulet 1995). The price elasticity is expected to be positive. That of non-price can either be positive or negative.

Issues in application

Peterson (1979) argues against using time series data in estimating long-run elasticities because only short-run year-to-year fluctuations are observed. McKay et al. (1998) opined that the output response to annual fluctuations is likely to be small (even after full adjustment) because farmers will respond strongly to price changes only if they are perceived to be permanent. This means that long-run elasticity estimates from time series data are biased downward. Similarly, Schiff and Montenegro (1995) argue that time series estimates are subject to the Lucas critique. The long-run supply response to prices is properly evaluated when the transition to a new price regime is detected. The values of the parameters estimated from time series data are specific only to a given policy regime, so one cannot forecast the impact of a policy reform. Although this is strictly true, long-run elasticities derived from time series analysis are at least indicative and while forecasting may not be done, inference can be drawn. If there is evidence of a long-run response, reforms that enhance the ability of farmers to respond – and increase the positive incentives to do so – may increase the long-run price elasticity further, thus promoting increased growth in agricultural output.

In time series analysis of a single commodity, the main difficulty lies in selecting the correct data. Apart from identifying the correct output measure (planted area, marketed production crop yields, etc.), researchers must determine which (relative) price variable should be used and the choice of deflator – consumer price index, input prices, other crop prices, etc. (Askari and Cummings, 1977). For example, if farmers formulate their price expectations using relative prices and yet an absolute price is used in estimation, results may incorrectly present farmers as not being responsive to price. Estimating aggregate supply response alleviates some of these problems. At an aggregate level, a major problem relates to the method of indexation (Colman and Ozanne, 1988). Typically, studies of aggregate supply response use the Laspeyres index. There are reservations about this index, however, and the divisia index has often been proposed as a better alternative because it uses weights from both the base and the comparison period. In situations where the weights (output shares of the different commodities) have changed little over the period considered, there should not be any significant divergence in the value of the two indexes and the choice of the index is not so critical.

Another essential theoretical issue is the formulation of the price expectation and X s (non-price factors) to include. Many authors use some distributed lag to capture price expectation, but the lag structure may vary from crop to crop. In general, perennial crops may have longer lags than annual crops. X s include variables describing marketing, credit, mechanization, land reforms, irrigation, weather and soil quality. In the Nerlovian model, weather (rainfall) and a time trend capturing structural change or advance in technology seem to be the favourites.

Another contentious issue in specification is the incorporation of risk variables. Although the economic consequences of instability in agriculture are not universally agreed upon, there is general recognition that risk does influence farmers' production decisions. If expectations are uncertain, a farmer's goal will generally not be profit maximization in the traditional sense but to obtain a maximum return in terms of income and safety. If risk does in fact have an important influence on farmers' production decisions, inclusion of variables representing risk in aggregate supply response models may be desirable in order to predict production more accurately, to improve estimates of other parameters in the model and as an aid in quantifying the impact of government policies that affect uncertainty as well as price. To date, few studies have focused on the econometric approach to risk response behaviour at both aggregate and individual levels. The traditional Nerlovian approach to analysing decision making by farmers has been concerned with the effect of price expectations formulated from past prices. The producer was assumed to maximize expected profit. For three decades, researchers (Just, 1974; Traill, 1978; Fu et al., 1986; Lin, 1992; Ghatak and Seale, 2001a/b) have incorporated risk into supply response using various formulations of risk to explain the variability of decision variables.

The concept of risk

The concept of risk as it affects behavioural decision making originated from the principle of Bernoullian expected utility, that is, the producer was assumed to maximize expected utility from profit (or other outcomes) rather than expected profit. According to Young (1979), it has been assumed by empiricists either that the underlying utility function was quadratic or that profit is normally distributed, yielding the function of mean and variance only. Hence, variance or standard deviation becomes that appropriate measure or risk. An increase in risk will have a negative effect on expected utility since farmers are generally recognized as being risk averse. Ostensibly, risk could have some influence on farmers' supply response through expected utility. Empirically, risk is measured as the difference between the expected and actual prices using geometric distributed lags on past prices to measure expected price (Just, 1974). Other measures include a moving standard deviation of past prices (Behrman, 1968) and Almon (polynomial) distributed lag formulations (Traill, 1978; Lin, 1992). The results of Just, (1974), Traill (1978) and Lin (1992) indicated the importance of including risk variables in supply analysis. In this study, the Just (1974) geometric distributed lag risk model with subjective quadratic risk variables is adopted to estimate the response of output supplied by Nigerian producers of agricultural commodities. The reduced form of the traditional Nerlovian partial adjustment and adaptive expectation dynamic model is used for comparison.

Given the summary of the Nerlovian model in Equation 5 as model 1, then:

$$Q_t = \beta_1 + \beta_2 P_{t-1} + \sum \beta_{3i} X_{it} + \beta_4 Q_{t-1} + \mu_t \quad (\text{model 1}) \tag{7}$$

The second model follows Just's (1974) risk model for which the risk variable is formed by geometrically weighting prices.

$$Q_t = \beta_1 + \beta_2 P_{t-1} + \sum \beta_{3i} X_{it} + \beta_4 Q_{t-1} + \beta_5 W_{it} + \mu_t \quad (\text{model 2}) \tag{8}$$

where

$$W_{it} = \sigma \sum_{k=0}^{\sigma} (1 - \sigma)^k (P_t - P_{t-1})^2 \tag{9}$$

(i = 1,2.....t, k = 0,1 2.....∞)

P_{t-1} , X_{it} , Q_{t-1} and μ_t are defined as before, while W_{it} is price risk of crop i in year t (the decision maker's subjective evaluation of the price of crop i in year t). σ is the geometric weighting parameter generated from a maximum likelihood search procedure using historical period data. $(1 - \sigma)^k$ is historical subjective risk associated with price in year t .

It would seem plausible to make a distinction between uncertainty and instability here. Unstable prices, if known in advance, would not be uncertain and so would not

induce any risk averse reaction. Uncertainty arises only from a divergence between actual and expected outcomes.

The hypothesis tested from the risk model is:

H_1 : Decisions are not significantly affected by subjective variance of prices of agricultural products

Just's (1974) solution to the problem was to define geometric lags on both prices and risk where risk is defined in terms of squared deviations between actual and expected prices and estimated via a two-dimensional maximum likelihood search over the unknown parameters. Berhman (1968) dropped any relationship between price expectations and risk in specifying the risk variable to be a moving standard deviation of past prices, that is,

$$\sqrt{\frac{1}{m-1} \sum_{j=1}^m \bar{p} - (p_{t-j})^2}$$

where m is the number of observations. He prespecified the weighting parameters as all being equal and specified risk in terms of total variability instead of the unexpected variability in prices. This allows direct estimation of Equation 6. Traill (1978) developed an iterative estimation technique where OLS cannot be applied.

For simplicity, only price risk is considered in this study. Yield risk may fairly readily be added either as a separate variable or combined with price risk to form a revenue risk. But for most crops and aggregates considered in this study, yield has been fairly stable relative to prices. In the few cases where it is considered, it does not improve the empirical results.

Time series problems

Last but not least, the Nerlovian approach used OLS to estimate the dynamic specification of the supply response. This means that the estimates of aggregate agricultural supply response are based on the assumption that the underlying data process is stationary. Most economic variables including agricultural time series tend to be non-stationary, however; i.e., their first two moments, means and variance are not constant. Using OLS with non-stationary variables may result in spurious regressions (Granger and Newbold, 1974). To ensure stationary variables, the equation could be reformulated in terms of differences, but this loses important information conveyed by the levels, such as information on long-run elasticities. To avoid this problem, cointegration analysis can be used (Banerjee et al., 1993). When combined with error correction model (ECM), it offers a means of obtaining consistent, yet distinct estimates of both long-run and short-run elasticities. Hallam and Zanolli (1993), Townsend and Thirtle (1995), Abdulai and Rieder (1995), and Townsend (1996) have used cointegration analysis and ECMs to estimate supply response at a commodity level on the basis that these approaches are preferable to the traditional Nerlovian dynamic model.

The dynamics of supply in the Nerlove model is driven by the partial adjustment hypothesis that farmers move closer to their equilibrium position by some fraction each

year. When variables are cointegrated (I, 1) there is a general and systematic tendency in the series to return to their equilibrium value; short-run discrepancies may be constantly occurring but they cannot grow indefinitely. This implies that the dynamics of adjustment are intrinsically embodied in the theory of cointegration, and in a more general way than encapsulated in the partial adjustment hypothesis. The Granger representation theorem states that if a set of variables is cointegrated (1,1), implying that the residual of the cointegrating expression is of order I(0), then there exists an ECM describing that relationship (see Appendix A).

The empirical model

Beginning with the Nerlovian partial adjustment and expectation dynamic model (7) and the risk model (8), the cointegration relations (10 to 13) are estimated using aggregated, subaggregated and individual crop data are as follows:

Model 1 (the Nerlovian model)

This can be written as:

$$A(L)Q_t = B(L)P_t + C(L)RER_t + \varepsilon_t \text{ for output response} \quad (10)$$

$$A(L)A_t = B(L)P_t + C(L)RER_t + \varepsilon_t \text{ for acreage response} \quad (11)$$

Model 2 (the risk model)

And this is designated as:

$$A(L)Q_t = B(L)P_t + C(L)RER_t + D(L)W_t + \varepsilon_t \text{ for output response} \quad (12)$$

$$A(L)A_t = B(L)P_t + C(L)RER_t + D(L)W_t + \varepsilon_t \text{ for acreage response} \quad (13)$$

where Q_t , A_t , P_t , RER_t , and W_t are total production, acreage, own price, real exchange rate and price risk, respectively. $A(L)$, $B(L)$, $C(L)$ and $D(L)$ are lag operators of order 1 to 4, while ε_t is the error term. In the results AL , EL , GL , TL , PL , COL , CVL , CWL and ML are added to the variables as prefix for aggregate, export, grains, roots and tubers, pulse, cocoa, cassava, cowpea, and maize. The variables are all logarithmic transformations of the first difference apart from price risk. If significant, a trend is included in the equation before testing for cointegration (see Appendix A).

The analysis

The analysis begins with examination of the time series properties of the variables used in this study. These properties are investigated and their order of integration determined

using the Augmented Dickey Fuller (ADF) unit root test. The ADF regression takes the form:

$$\Delta X_t = \beta_0 + \beta_1 X_{t-1} + \beta_2 \sum \Delta X_{t-i} + \mu \quad (14)$$

where X_t represents the individual explanatory variable at time t . Δ indicates the difference term. The test is against the null hypothesis, $H_0: \beta_1 = 0$. Rejection of the null hypothesis suggests that the series is non-stationary and has to be differenced at least once in order to make it stationary. The ADF test is performed by including up to four lag lengths (Dickey and Fuller, 1979).

If H_0 cannot be rejected, then X_t contains a unit root and hence it is not stationary. If its first difference is then tested and found stationary, X_t is $I(1)$. If not, X_t needs to be differenced further. Given that X_t is $I(1)$, the analysis proceeds to test for cointegrating relationship. As producer prices are generally fixed and announced by the Nigeria government before the harvesting season, aggregate producer price is likely to cause agricultural production and not vice-versa. Without running tests on causality, we can reasonably assume that Q_t or A_t is the dependent variable. Against this background, the analysis proceeds thus: First the dynamic specifications of the model in equations 12 and 13 were estimated. Next is the ADF and Johansen test for cointegrating relations (see Appendix A). Then, where cointegration exists, ECM is estimated. If not, the analysis continues with ADL modelling of the supply response.

Test for structural break

To test for structural break the study adopts Perron (1989). The main concern of Perron (1989) is to determine whether structural breaks in a “trend-stationary” series may reverse a failure to reject the null hypothesis of a unit root, i.e., a random walk with possible non-zero drift. In testing for stationarity, Perron includes a trend shift dummy variable and tests for its significance. In essence, it is a Phillips–Perron unit root test with the inclusion of dummy variables as well. While there are other methods to test for structural breaks (such as the Chow test or other recursive residual regressions) that can be run, these tests don’t properly address the unit root question.

The Perron procedure also has its drawbacks. While a Chow test systematically, and with no prior assumptions, tests for the presence of a structural break at each observation, the Perron procedure is explicitly *conditional* on the date of the posited break. A test that could simultaneously check for the date of possible structural breaks *and* one in which the trend-stationary/difference stationary question is answered would be ideal, but alas, it has not yet been developed. For the purposes of this paper, however, the technique is sufficient because we are interested in testing for the a priori belief that a shock occurred in 1986. While Perron tests for three possible kinds of breaks – a “crash”, a change in the growth trend and a combination of both – the response variables and price series seem to exhibit possible changes in growth trends, and so the structural break tests will be of Perron’s Model (A), the “changing growth” model. The regression equation is of the form:

$$y_t = \mu + \beta t + \gamma sap_t + \alpha y_{t-1} + \sum_{i=1}^k \Delta y_{t-i} + \varepsilon_t$$

where μ is the intercept term, β is the linear time trend coefficient, γ is the coefficient for sap where $sap = t - Tb$ if $t > Tb$ and 0 otherwise. Tb refers to the time of the break where Tb is the number of the observation at that break. The summation term contains the relevant number of lagged difference terms. Estimation and interpretation of this equation for each of the variables in question is the ultimate goal of this section. Significance of γ and α is of particular importance. A significant γ coefficient indicates the presence of a structural break and change in trend of the variable. An α significantly close to one indicates the presence of a unit root, i.e., the series is difference stationary rather than trend stationary. The hypothesis is that many series may have an α close to one in a normal ADF test with an intercept and time trend, but that when a shift parameter is included and is significant, the α term may no longer be significantly close to one.

Variable measurements

Beginning with own price effects, this section looks into the techniques for measuring the variables in question. The other variables are real exchange rate effects, risk effects, stock adjustment effects and institutional effects.

Own price effects

The price and quantity indexes were constructed using a Laspeyres formula. The Laspeyres price and quantity indexes may be expressed as:

$$P_t = \left(\frac{\sum P_t Q_0}{\sum P_0 Q_0} \right) 100 \quad (15)$$

$$Q_t = \left(\frac{\sum P_0 Q_t}{\sum P_0 Q_0} \right) 100 \quad (16)$$

where P_t is the price index and Q_t is the quantity index.

The period covered is 1970–2003 with indexes benchmarked to 1985 ($Q_0 = P_0 = Q_{1985} = P_{1985} = 100$). The quantity indexes are expressed per capita (dividing by an index of total population) and the price indexes are in real terms. To achieve this, the producer prices were deflated by the consumer price index (CPI). The commodities in the indexes are cocoa, cassava, maize, and cowpea representing export, roots and tubers, grains, and pulse crops, respectively. These crops are the most widely grown of each commodity aggregate in Nigeria.

The coefficient of own price is expected to be positive. During the CMB era, prices were set and announced after planting. A major objective of the board was to operate a year-to-year smoothing of the producer prices. Assuming impossibility of smuggling produce in from or out to neighbouring territories, the price formation model was hypothesized to be naive (4).

Real exchange rate effects

Real exchange rate is included to stress the importance of Dutch disease in the Nigerian economy. The seeming relationship between the exploitation of crude oil and the decline in agricultural sector stimulated the devaluation of the nation's currency in 1986 (Osuntogun et al., 1993). The basis is that increased oil revenue makes other sectors, especially agriculture, less competitive. The oil boom has two major effects on the agricultural sector: a shift of national expenditure to the oil sector and a downturn in the prices of agricultural commodities. Since there has been less technological growth in Nigeria's economy, its comparative advantage in agriculture began to shrink. Other harmful effects of the Dutch disease in Nigeria include corruption and protectionist policies such as the CMBs, which adversely affects the agricultural sector.

One of the ways employed in Nigeria to reduce the threat of Dutch disease is slowing the appreciation of the real exchange rate and boosting the competitiveness of the agricultural sector as embedded in the SAP. According to Obadan (1997), a central issue in SAP is the removal of distortions in the economy that have prevented proper allocation of resources. As part of the measures taken under SAP, trade was liberalized, price controls and import licensing were removed, and exchange rate reforms were introduced. The policy resulted in consistent depreciation of the nation's currency against other convertible currencies. This was supposed to lead to expenditure switching and production of tradeables, higher export but lower imports, and an improved external payments position for the country.

Several researchers have examined the effects of the exchange rate policy on agricultural and manufacturing sectors in Nigeria. Ojo (1978), Osagie (1985) and Ajayi (1998) discovered that exchange rate devaluation is stagflationary and has no significant effects on external trade. Ajilima and Agba (1986) looked at the impact of floating exchange rate on non-oil export and concluded that foreign exchange market liberalization will not be able to enhance non-oil exports because the problem is not that of low price per se but of stagnation of production, especially in the agricultural and manufacturing sectors. Kwanashie et al. (1998) investigated the time path of non-oil exports in order to identify their response to liberalization policy in Nigeria and discovered that it has not had any impact. Taiwo (1990) investigated the determinants of non-oil export in Nigeria. He disaggregated non-oil export into two categories – agriculture and manufactured. The supply function had three arguments – relative prices, capacity output and oil revenue. The first two were positively related to export supply, the third had an inverse relationship to confirm the existence of Dutch disease in the Nigeria economy. Other literature on Nigeria's Dutch disease includes Oyejide (1986), Pinto (1988), Osuntogun et al. (1993), and Ekpo and Egwakhide (1994). Most of these studies were static in nature, thus this study proceeds to give dynamism to the relationship between real exchange rate and agricultural production in Nigeria at individual crop level. For the export crop (cocoa), the nearest competitive crops are the food crops, maize, cowpea and cassava.

In order to facilitate discussion on the Dutch disease in the Nigerian economy, the following purchasing power parity (PPP) theory condition is adopted in this study:

$$RER = NER * PF/PD$$

where PF is a foreign price using the indexes for world price (WPI) and PD is the domestic price measured in real terms. It is expected that the movement of the real exchange rate would capture the substitution effects both in production and consumption (between traded and non-traded goods such as export crops and food crops or between food imports and domestic production). It is difficult to make an assumption about the signs of the coefficient, since the impact of changes in real exchange rate would be mixed for exportable cash crops and food imports. For example, it might assume a negative sign as the real exchange rate appreciates, leading to an improvement in the competitiveness of export crops (making exports cheaper abroad), but the same movement would make food imports more expensive domestically.

Risk effects

Only price risk is considered because yield is fairly stable. The observation on price risk is measured as the square deviation of the expected price from the actual price (7). The coefficient of the risk variable is expected to be negative.

Stock adjustment effects

Quantity supplied in the last crop year was used as a proxy for stock adjustment.

Institutional effects

To capture the effects of the regime change, dummy variables (both additive and interactions with relevant explanatory variables where the slope may change between the CMB and SAP periods) are introduced. Denoting the dummy variable by D , with D being the dummy for the structural adjustment in Nigeria, then $D = 1$ if $t > \text{year } 1986$ and 0 if $t < \text{year } 1986$.

Time series properties

Results of the unit root test are given in Appendix B (Tables B1 and B2). For the national aggregate data, the hypothesis of a unit root cannot be rejected at the 5% level except for price risk (W). On the other hand, when the first differences are tested, the null hypothesis can be rejected at the 5% level. In the case of aggregate export crops, none of the variables are stationary at level price risk (W). All the variables, however, are stationary after the first difference, hence $I(1)$.

Quite similar results are obtained in the case of aggregate grains, tubers and pulse. At levels, the hypothesis of a unit root cannot be rejected except for price risk (W). They are all stationary after the first difference, however. A similar result is obtained in case of individual crops. They are all stationary after the first difference.

The results of the Phillips–Perron test of structural break are summarized in Appendix B, Table B3. There are reasons to suspect that SAP significantly affects output and price of agricultural commodities in Nigeria at both aggregate and specific crop levels. The

structural dummies are significant in both. Rejection of the null is difficult, perhaps because of the relatively small samples.

Basically, the presence of $I(1)$ variables implies that most if not all test statistics will have non-standard distributions. Thus, one cannot automatically refer conventional test statistics to the standard t , $N(0,1)$, F or chi-square tables. From Johnston and Dinardo (1997), we know that if in a reparameterization, a subset of parameters can be expressed as coefficients of mean-zero, $I(0)$ variables, then conventional tests on that subset are asymptotically valid. Two things are feasible for estimation: (a) reparameterization can be carried out and the parameters estimated and tested by applying OLS; (b) We can test for a cointegrating relationship between the corresponding dependent variable and the sets of explanatory variables for national, aggregate and individual crops. The latter is considered in this study since reparameterization may weaken economic interpretation of the coefficient estimates.

The results of the test for cointegration are summarized in Appendix B (Table B3). The ADF tests were applied using PC-GIVE and the trace and eigenvalue tests using PC-FIML. There is no cointegrating relationship for grains, roots and tubers and maize supply response functions.

4. Empirical results and analysis

For grains, roots and tubers, and maize, ADL modelling was carried out even when price risk was not included in the model. For all other groups and individual crops, the analysis involved estimation of an error correction model. Results for the total price series, export crop price series, grain price series, pulse price series and tuber price series are shown (Appendix C, Figures C1–C5, respectively).

The response variable: Trends of cultivated area, yield and production

It is important to inquire whether the relationship between production and area cultivated can satisfy the foregoing discussion. That is, how could the problem of choice of dependent variable be resolved in the Nigerian context? The growth rates of the three variables and how they move together is depicted in Figures C6 to C10 in Appendix C. The rate at which output, yield and acreage grew at national level is presented in Figure C6. The figure shows that in the pre-SAP period the rate grew slowly but was stable compared with the growth in the first decade of the post-SAP period (1987–1997). This has been attributed to abolition of NCB, which reversed prices of good set that has been traditionally low (Idowu, 1986; Adegeye, 1986; Ajakaiye, 1987; Oyejide, 1990; Alimi and Awoyomi, 1995). The rate of growth slowed down tremendously in 1999 partially because of the political transition from a military to a civilian regime, but mainly because the momentum to reform agricultural prices appeared to have run out of steam as the rate of growth did continue to be slow but not stable even after the 1999 experience. Although Nigerian agriculture could still be said to progress quite well at aggregate level following the inception of SAP in 1986, acreage and yield did not grow along. In fact, in some years sown acreage actually declined Appendix C (Figure C6). Hence a substantial increase in production must occur by increasing yields through more intensive use of technology.

At the subaggregate level, the rate of growth followed the pattern of the aggregate except for tubers (Figures C7 to C10). Acreage and yield did not grow at the same rate as output and the rate of growth in the first decade following introduction of SAP was much faster than the rate in recent time. Generally, the exact role of the SAP pricing incentive in maintaining increased production and supply needs closer observation. There is therefore a need to capture not just the effect of price changes but also the impact of price risk.

Generally, going by Figures C6 to C10, the major source of fluctuation in the production of food and export crops in Nigeria has been area rather than yield. The contribution of area has been by far more conspicuous than yield growth. While fluctuation of output is more salient, that of yield was not that expressive. In contrast, not only does area fluctuate notably, but also its pattern tends to correspond fairly to that of output. Hence, in this study output and area response behaviour were modelled, which distinguished between area elasticity of output and other elasticities. Moreover, the use of production as the dependent variable has been adjudged the best of the three as it acknowledges that farmers may respond to price incentives by using either intensive or extensive farming method.

Estimation results

This section presents and discusses results of the estimation of the two dynamic models in (6) and (7); since the risk variable (LW) is $I(0)$ there seems to be no ground for analysis of cointegration using the variable. It is not possible therefore to examine a cointegration relationship using the Just risk model. The modelling is therefore done using an autoregressive distributed lag model (ADL) (see Appendix A) for aggregate, commodity aggregates and individual crops. In running the regression, up to four lags were imposed and the estimation proceeded by dropping those variables with low t-values - the preferred equations are in Appendix D. Moving from the general to specific modelling of the ADL model improves the information criteria, specifically the Schwartz criterion (SC), Hannan and Quinn (HQ) and the forecast prediction error (FPE). They decline as the less significant variables and lags are dropped on the basis of low t-values. At the same time, the equation standard error(s) increase; nevertheless, price and price risk are sometimes retained even if their t-values are low because they are being particularly investigated. The stability of the regression parameters are confirmed using cusum of square test. The results are shown in Appendix E, Figures E1 to E9.

National aggregate

The result of the dynamic ADL for national aggregate is shown in Appendix D (Table D1). As expected a priori the aggregate output is positively responsive to its second lag, $AQt-2$, the numerical value of the coefficient is about 0.25 and is statistically significant at 5% level. The statistic shows a fair degree of persistence in adjustment of stock as the current level of agricultural production reflects about 0.25 of its value two years ago. The price coefficient is small (0.094) and statistically significant in the second lag ($ALPt-2$), which is plausible given the heavy oil dependence of the economy and slow rate of resource base diversification. The coefficient of price risk is close to unity (0.951) and significantly negative as expected; the results suggest that price risk needs to be meaningfully reduced for agricultural output to increase in Nigeria. The coefficient of the SAP dummy is positive and significant when in association with the price variable but negative and significant when in interaction with price risk, implying that SAP enhances increase in aggregate production when in interaction with price. When price risk is removed from the model, other variables are $I(1)$. Hence the analysis proceeds with test

for cointegration. There is fairly consistent evidence that the cointegration relationship for ALQt is with respect to own price, real exchange rate and trend.

The solved static long-run equation is:

$$ALQt = 0.375ALPt + 0.027 ALRER + 0.061D - 0.316D*ALP - 0.00 IT$$

A rise in either producer price or real exchange rate has a positive and significant effect on aggregate output. Over the long run, producers are price responsive and devaluation of the nation's currency seems to be making positive impact on the aggregate production. The tendency of devaluation to give rise to an increase in aggregate production in the long run is obvious.

Appendix D (Table D2) reports estimates of ECM and the short-run dynamic model for aggregate production. The short-run elasticity with respect to price, *ALP*, is significant and about 0.304. The coefficient of *ECM* is negative but insignificant as expected a priori. This result is consistent with the report of McKay et. al. (1998). Aggregate response to price changes in the short run is smaller than in the long run. The positive impact of *SAP* is evident from the significance of the *SAP* dummy coefficient, *D*, and its interaction with the price variable, *D*ALP*. This suggests that liberalization of the agricultural market in Nigeria exacts a positive effect on agricultural output despite its stringent conditions. This experience is similar to that obtained recently in Chinese agriculture (Ghatak and Seal, 2001a) as *SAP* is a dominant factor responsible for increase in output.

Commodity aggregate

The results for dynamic ADL modelling including price risk for commodity aggregate – export crops, grains, pulse and roots and tuber crops – are presented in Appendix D, Tables D3– D10.

Export. Turning to export, we see that modelling with production as the dependent variable gave better results than area response, hence the discussion is based on output response. Moving from ADL general to specific modelling, the preferred equation including price risk has seven variables and 29 observations (Table D3). The coefficient on the stock adjustment variable is negative and significantly related to aggregate export crop production, suggesting that the producers are not price and price risk responsive, although exchange rate (lagged one and two years) influences the output positively. This agrees with Jaeger (1992) that increase in exchange rate gives rise to increase in agricultural production from time to time while producer price is insignificant. The tendency of devaluation to promote production of export crops is obvious.

Table D4 reports estimates of the short-run relationships for export crops without price risk. The balance of the various tests suggest that export crop producers respond to own price and exchange rate in the long run, the solved static long-run equation is:

$$ELQt = 0.009ELP + 0.0501ELRER + 0.037T$$

The evidence suggests that production of export crops has increased as a result of increase in price and exchange rate. The estimate of the ECM shows that the short-run

exchange rate elasticity is 0.034 while the stock adjustment coefficient is -0.554. The coefficient of the ECM is negative but insignificant. Price coefficient is also not significant in the short run.

Grain. The results for grains (Table D5) include three-year lagged area, current price and its four-year lag, current exchange rate and its three-year lag, and three- and four-year lag of price risk, as well as the SAP dummy in interaction with price and price risk in the preferred equation. Unlike the national aggregate and export models, area response performed better than that of output in terms of various test statistics (R², DW, FPE and RSS). Hence this report is based on modelling area response.

All the variables except the SAP dummy in association with the price variable are positive and significant at the 5% level. The coefficient of land area is 0.34 and statistically significant in the third-year lag. The land area response to current price is more important than the fourth-year lag, although both are positive and significant at the 5% level. Similarly, current exchange rate has a more significant impact on land area than its third-year lag. Various policy measures to stabilize the exchange rate seem to be getting positive response from grain producers in terms of expansion of the land area under cultivation. Contrary to expectation, price risk (both third-year lag and fourth-year lag) has positive and significant effects on land area committed to grain production. A possible reason for this trend is the increase in the number of price risk management techniques available to grain producers, such as agricultural insurance, modification of domestic storage policies, the use of consumer subsidies, and various modifications of restrictions on trade in grains to increase domestic production such as tariffs, taxes and outright ban.

Modelling grain area without price risk does not support estimating an ECM (Table D6). The estimation is also done using ADL model. The result indicates that grains appear to be trend stationary; the positive sign on the coefficient of price (current and fourth-year lag) is perhaps indicating some intercropping or complementarity in production in the short run.

Roots and tubers. In respect of roots and tubers, like other non-tradeable commodity aggregates, ADL modelling of the area response gave a better result than output. The result is presented in Appendix D (Table D7). The preferred equation contains five variables: land area (lagged three years), price (lagged two years), price risk (lagged two years), real exchange rate (lagged two years) and SAP dummy. All the variables are statistically significant with expected signs except price risk and cultivated land area (lagged three years). The crop is inelastic to both price and real exchange rate. A 100% rise in own price will give rise to about a 10% rise in cultivated land area, while a similar rise in real exchange rate will lead to a decline in cultivated land area by about 10%. This indicates a slight shift from growing of roots and tubers to raising export crops. When price risk is removed, there is no evidence of a cointegrating relationship. Hence the modelling is still done using ADL (Table D8). Basically the results are similar. Obvious differences include the fact that the crop is more inelastic to price but less inelastic to real exchange rate. The results here corroborate the findings of Ghatak and Seale (2001a), who discovered that response to price risk is generally inelastic. This may be due to the

measure of price risk adopted, however, since this study and Ghatak (2001a) utilized the same type of measurement.

Pulses. The result of the ADL modelling of pulses is in Table D9. The response of acreage to previous years' (second and fourth lag) land area is consistently negative and statistically significant. This might be due to incessant problems of property rights, especially in the northern part of the country where the bulk of pulses (cowpea in particular) is grown. As expected, acreage response to price is positive and statistically significant. The effect of real exchange rate on pulse acreage is negative, perhaps because of diversification into export crop enterprise. The coefficient of price risk is negative and significant at the 5% level as expected. There is evidence of cointegration when price risk and its interaction with SAP dummy are not included in the model. The solved long-run static equation is:

$$PDLA = 0.096 PLP - 0.075 PLRER + 0.176 D - 0.00015D*PLP$$

A rise in the market price has a positive and significant effect on the acreage of pulse in the long run; a change in price will lead to about 0.1ha increase in land area. On the other hand, the effect of exchange rate is negative but also inelastic. An appreciation of the exchange rate will cause a small decline in land area. The result suggests that the level of the real exchange rate has minimal policy implication for the expansion of pulse production via an increase in cultivated land area. The current changes depend largely on their past values and the impact of the long run presented by the ECM term. The results of the ECM and short-run dynamic model are presented in Table D10. In the short run, the own price elasticity (0.15) and that of real exchange rate (0.03) are greater than the long-run estimate. The adoption of SAP enhances the expansion of land area allocated to production of pulse as shown by the significance of the SAP dummy (*D*)

Cocoa: Appendix D, Tables D11 and D12, present ADL modelling of cocoa acreage response and error correction estimates, respectively. Table D11 shows that the producers are not price and price risk responsive. Cultivated land area (lagged four years), real exchange rate (lagged one year) and SAP dummies are major determinants of cocoa acreage response. The coefficients of both land area and exchange rate are negative and significantly related to cocoa acreage. As it affects cocoa, there seems to be no more justification for further devaluation of the nation's currency. When price risk is removed, the results of the short-run dynamic and ECM model (Table D12) show that previous year's cocoa acreage is the most significant predictor of current acreage. The elasticity is 3.213. Deviation from long-run equilibrium as shown by the ECM is significant at the 5% level. The long-run static equation is:

$$COLA = -0.123COLP - 0.093COLRER + 0.02T$$

The cocoa producers respond to both own price and real exchange rate in the long run. The two elasticities move in the same direction in that an increase in both price and exchange rate is not sufficient to stimulate increase in cocoa acreage, which is already declining because of the old age and neglect of rehabilitation of existing trees. The response is lower than those obtained by previous research work on Nigerian cocoa

supply response: 0.20 (Olayide 1972), 1.29 (Stern, 1965) and 0.45 (Berhman, 1968) and others.

Cassava: Table D13 reports the results of the ADL modelling of cassava acreage response. Previous year cultivated land area is a positive and significant predictor of current cassava acreage. The farmers are both price and price risk responsive. The coefficient of price risk is positive, however, contrary to theoretical expectation. This is perhaps because of improved risk management strategies, which has led to development of many cassava cultivars. Table D14 reports the results of modelling cassava acreage response without price risk. The cointegration test result support the estimation of ECM. The solved static long-run equation is:

$$CVLA = 0.130CVLP + CVLRER + 0.076D + 0.080D*LP$$

Increase in price has an impact similar to that of real exchange rate in the long run. Over the long run, the farmers have been responsive to real exchange rate in switching between cassava and cocoa, which is an export crop. As expected, the ECM's coefficient is negative and insignificant.

Cowpea: Appendix D (Tables D15 and D16) gives the estimates of the ADL modelling and error correction of cowpea acreage response. Inclusion of price risk and modelling with ADL gives a better result than when it is removed. The farmers are both price and price risk responsive. Like other crops considered, cultivated land area performed better than the output as the response variable. The crop is inelastic to price (lagged two and three years), price risk (lagged two and three years) and real exchange rate (lagged two and three years). The effect of structural change represented by the SAP dummy is positive and significantly related to cowpea acreage. The result of the ECM and short-run dynamic analysis indicates that SAP is the dominant factor responsible for shift in cowpea supply. The solved long-run static equation is:

$$CWLA = 0.952CWLP - 0.09CWLREER$$

The two elasticities offset each other in the long run. A 100% rise in price will give rise to about 95% increase in cowpea cultivated land area, while a similar rise in real exchange rate will lead to less than 10% decline in the long run.

Maize: Tables D17 and D18 in Appendix D summarize the estimates of maize acreage response using ADL modelling whether price risk is included or not. This is because the analysis does not support a cointegrating relationship for maize acreage with the explanatory variables. Modelling with price risk as one of the explanatory variables indicates that farmers are not price but price risk responsive. The crop is elastic to price risk. The elasticity is 1.195 and adheres to expectations of a negative and significant relationship. The effect of cultivated land area (lagged two years) and real exchange rate are similar. An increase in any one of them is associated with an increase in cultivated land area. When price risk is removed from the model, only exchange rate remains significant at 10%.

5. Conclusions and policy implications

This study modelled the production and supply response in Nigerian agriculture to include both the standard arguments and risk. By estimating ADL and error correction models for aggregate, commodity aggregates and individual crops using time series data that span over three decades (1970–2003), the study derives both the short-run and long-run elasticities. Generally, the results show that the model that includes price risk in the argument predicted better than the other without price risk, perhaps because of structural changes. The results for individual crops are more robust than for those of the aggregate in terms of both test statistics and economic meaning of the parameter as given by the signs and magnitudes of the coefficients. Following the assertion of Pope (1981), an increase in dispersion of expectations could decrease aggregate supply if the supply were strictly concave. Another possible reason is that during an unstable period (like the SAP era) the price expectation of individual crops could vary widely, thus generating instability of aggregate supply.

On the whole, the results of the empirical analysis suggest that producers are responsive not only to price but also to price risk and exchange rate. This is consistent with the evidence of agricultural sector growth following the SAP. Price risk needs to be adequately reduced if meaningful improvement in production is to be gained from the price incentive inherent in ongoing national economic reforms. In this respect, emerging commodity exchanges and futures markets should be given greater attention and made fully operational.

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Appendix A: Test for cointegration

Engle and Granger (1984)

Consider the following single equation:

$$p_{1t} = \beta p_{2t} + \mu_t \tag{A1}$$

If μ_t is non stationary, then $p_{1t} - \beta p_{2t}$ is not a cointegrating relationship. Engle and Granger suggest estimating A1 by OLS and applying unit root tests such as the ADF and Phillips-Perron Z_t or Z_p to the estimated residuals $\hat{\mu}_t$, in order to test the null hypothesis of no cointegration. For a discussion on the issues related to the Engle and Granger method see Maddala and Kim (1998).

Johansen (1988, 1995)

Consider a vector autoregression (or VAR) of two variables p_{1t} and p_{2t} . A VAR expresses a vector of variables as a linear sum of a set of lags of itself. A simple case of a VAR between two variables is:

$$\begin{pmatrix} p_{1t} \\ p_{2t} \end{pmatrix} = \begin{pmatrix} \mu_1 \\ \mu_2 \end{pmatrix} + \begin{pmatrix} \alpha_1 & \alpha_2 \\ \alpha_2 & \alpha_2 \end{pmatrix} \begin{pmatrix} p_{1t-1} \\ p_{2t-1} \end{pmatrix} + \begin{pmatrix} v_{1t} \\ v_{2t} \end{pmatrix} \tag{A2}$$

The issue of cointegration can once again be addressed by looking at the VAR, but extending it to contain a second lag. An example of a VAR(2) would be

$$\begin{pmatrix} p_{1t} \\ p_{2t} \end{pmatrix} = \begin{pmatrix} \mu_1 \\ \mu_2 \end{pmatrix} + A_1 \begin{pmatrix} p_{1t-1} \\ p_{2t-1} \end{pmatrix} + A_2 \begin{pmatrix} p_{1t-2} \\ p_{2t-2} \end{pmatrix} + \begin{pmatrix} v_{1t} \\ v_{2t} \end{pmatrix} \tag{A3}$$

This has the vector error correction (VECM) representation:

$$\begin{pmatrix} \Delta p_{1t} \\ \Delta p_{2t} \end{pmatrix} = \begin{pmatrix} \mu_1 \\ \mu_2 \end{pmatrix} + (A_1 + A_2 - I) \begin{pmatrix} p_{1t-1} \\ p_{2t-1} \end{pmatrix} + \begin{pmatrix} v_{1t} \\ v_{2t} \end{pmatrix} \quad (\text{A4})$$

The rank of the matrix $(A_1 + A_2 - I)$ is equal to the number of cointegrating vectors. If the rank of $(A_1 + A_2 - I)$ is equal to two, then both variables can be shown to be stationary. If the rank of $(A_1 + A_2 - I)$ is zero then the series are not cointegrated, while if the rank of $(A_1 + A_2 - I)$ is one, then the variables are cointegrated.

Therefore, in case of two variables, cointegration can be tested by testing the significance of the characteristic roots or the eigenvalues of $(A_1 + A_2 - I)$. If the variables are not cointegrated, the characteristic roots λ_1, λ_2 are equal to zero. Similarly if the rank of $(A_1 + A_2 - I)$ is equal to one, $0 < \lambda_1 < 1$ and λ_2 is equal to zero. Johansen (1988, 1995) derived the distribution of two test statistics for the null of no cointegration referred to as the trace and the maximum eigenvalue test:

$$\lambda_{\text{trace}} = -T \sum_{r=1}^2 \ln(1 - \lambda_r) \quad (\text{A5})$$

$$\lambda_{\text{max}} = -T \ln(1 - \lambda_1) \quad (\text{A6})$$

The first statistic tests the null hypothesis that the number of independent cointegrating parameters is less than or equal to two, whilst the second statistic tests the null hypothesis that the number of cointegrating parameters is one against the alternative of two cointegrating parameters.

Johansen derived an error correction representation of a cointegrating system. He defined two $(n \times r)$ matrixes, α and β , where n is the number of variables and r is the rank of $(A_1 + A_2 - I)$. The properties of these matrixes are:

$$(A_1 + A_2 - I) = \alpha\beta, \quad (\text{A7})$$

The matrix b is the matrix of cointegrating parameters, whilst the matrix a represents the adjustment of the variables towards the long-run equilibrium, if it exists. In the case of two variables, such as p_{1t} and p_{2t} , the error correction model (ECM) is as follows:

$$\begin{pmatrix} \Delta p_{1t} \\ \Delta p_{2t} \end{pmatrix} = \begin{pmatrix} \mu_1 \\ \mu_2 \end{pmatrix} + \begin{pmatrix} \alpha_1 \\ \alpha_2 \end{pmatrix} (p_{1t-1} - \beta_{t-2}) - A_2 \begin{pmatrix} \Delta p_{1t-1} \\ \Delta p_{2t-1} \end{pmatrix} + \begin{pmatrix} v_{1t} \\ v_{2t} \end{pmatrix} \quad (A8)$$

β represents the long run multipliers where a rank restriction has been imposed:

$$\frac{\alpha_1}{1-\alpha_1} = \frac{\alpha_2}{1-\alpha_2} = \beta \quad (A9)$$

In this case the lack of a cointegrating relationship would also imply no Granger causality between the series, but if only $A_2 = 0$. More generally, Granger causality does not require cointegration. However, cointegration does imply causality in at least one direction.

Autoregressive distributed lag (ADL) models and cointegration

An ADL model can be written as:

$$p_{it} = a + \sum_{j=1}^j \beta_j p_{1t-j} + \sum_{k=0}^k \gamma_k p_{2t-k} + \varphi T + \varepsilon_t \quad (A10)$$

where p_{it} $i = 1, 2$, are series of variable p , a is an intercept, T is a time trend and ε_t is the error term.

A key issue in estimating ADLs is the identification of the correct number of lag length. Under-parameterization can lead to misspecification, while over-parameterization limits the degree of freedoms and increases forecast variance. Normally the relevant j and k are selected by means of information criteria such as the Akaike, Schwartz–Bayes, the Hannan Quinn and log likelihood.

In the long-run equilibrium $p_{1t} = p_{1t-k} \forall j$ and $p_{2t} = p_{2t-k} \forall k$ and then the long-run response of p_{1t} to a change in p_{2t} is given by:

$$\delta_1 = \frac{\sum_k \gamma_k}{1 - \sum_j \beta_j} \quad (A11)$$

Appendixes

Consequently, the long-run equilibrium relationship can be written as follows:

$$p_{1t} = \delta_0 + \delta_1 p_{2t} + \mu_t \quad (\text{A12})$$

where

$$\delta_0 = \frac{\alpha}{1 - \sum_j \beta_j} + \frac{\varphi}{1 - \sum_j \beta_j} \quad (\text{A13})$$

As from (A13) $1 - \sum_j \beta_j = \frac{\sum_k \gamma_k}{\delta_1}$, the ECM representation of the ADL (A10) can be written as:

$$\begin{aligned} \Delta p_{1t} = & \alpha - \left(1 - \sum_j \beta_j \right) (p_{1t-1} - \delta_0 - \delta_1 p_{2t-1}) + \sum_{j=1}^j \beta_j \Delta p_{1t-j} \\ & + \sum \gamma_k \Delta p_{2t-k} + \varepsilon_t \end{aligned} \quad (\text{A14})$$

where $1 - \sum_j \beta_j$ is the error correction coefficient.

Appendix B: Time series properties of data and cointegration test

Table B1: Unit root tests for national and commodity aggregates

Variable integration	t-ADF Level	t-ADF 1 st difference	Order of
ALQt	-2.036	-3.479*	1
ALAt	-1.426	-6.809**	1
ALPt	-2.119	-6.105**	1
ALRERt	-2.268	-8.843**	1
ALWt	-3.717*	-7.018**	0
ELQt	-2.829	-8,747**	1
ELAt	-2.837	-7.012**	1
ELPt	-2.980	-9.309**	1
ELRERt	-1.478	-9.278**	1
ELWt	-3.651*	-7.887**	0
GLQt	-2.101	-4.243*	1
GLAt	-3.075	-6.262**	1
GLPt	-2.396	-4.305*	1
GLRERt	-1.354	-8.324**	1
GLWt	-4.296*	-6.978**	0
TLQt	-1.902	-3.530*	1
TLAt	-2.084	-5.206**	1
TLPt	-1.976	-6.944**	1
TLRERt	-1.974	-7.566**	1
TLWt	-5.872**	-9.303**	0
PLQt	-1.875	-5.230**	1
PLAt	-1.529	-6.306**	1
PLPt	-2.065	-5.766**	1
PLRERt	-2.356	-8.441**	
PLWt	-3.489*	-8.311**	

** , * = indicates significant at 1% and 5% levels, respectively. L = natural logarithm
unit root test include constant and trend values. Critical values: 5% = 3.47, 1% = -4.08

Table B2: Unit root tests for individual crops

Variable	t-ADF Level	t-ADF 1 st difference	Order of integration
COLQt	-1.584	-9.472	1
COLAt	-2.248	-6.223	1
COLPt	-3.473	-6.255	1
COLRERt	-3.074	-6.778	1
COLWt	-5.854	-12.725	0
CVLQt	-1.439	-4.540	1
CVLAt	-1.963	-6.124	1
CVLPt	-1.972	-6.151	1
CVLRERt	-2.007	-5.096	1
CVLWt	-5.600	-8.250	0
CWLQt	-2.177	-5.150	1
CWLAt	-2.364	-5.330	1
CWLPt	-1.764	-5.847	1
CWLRERt	-2.002	-5.803	1
CWLWt	-5.336	-8.963	0
MLQt	-1.299	-5.618	1
MLAt	-1.824	-5.170	1
MLPt	-1.908	-5.764	1
MLRERt	-2.074	-6.392	1
MLWt	-4.327	-7.615	0

** , * = indicates significant at 1% and 5% levels, respectively. L = natural logarithm
unit root test include constant and trend values. Critical values: 5% = 3.47, 1% = -4.08

Table B3: Results of Structural Break Tests

Output series									
Series	K	μ	t-stat	\bar{a}	t-stat	\hat{a}	t-stat	\acute{a}	t-stat
Nation	3	0.903	3.411	0.050	1.125	0.008	2.129	-0.219	-3.259
Export	4	4.228	1.943	0.190	1.341	0.008	0.904	-0.363	-1.967
Grain	4	1.753	2.601	0.084	0.844	0.022	3.148	-0.474	-2.673
Pulse	5	0.914	1.562	0.312	2.963	0.004	0.317	-0.216	-1.333
Tuber	4	0.555	2.120	0.199	2.137	0.003	0.048	-0.122	-1.864
Cocoa	4	4.220	1.843	0.190	1.347	0.006	0.904	-0.364	-1.977
Cassava	5	3.360	1.879	0.089	1.110	0.006	0.716	-0.210	-1.822
Cowpea	5	4.247	2.794	0.216	1.741	0.015	1.533	-0.336	-2.190
Maize	4	6.176	4.387	0.365	1.661	0.029	3.053	-0.477	-4.506
Price series									
Series	K	μ	t-stat	\bar{a}	t-stat	\hat{a}	t-stat	\acute{a}	t-stat
Nation	4	0.453	1.689	0.554	1.718	0.555	1.817	-0.456	-2.358
Export	4	3.958	2.846	1.089	2.529	-0.087	-2.888	-0.652	-2.715
Grain	4	0.384	1.250	0.395	0.944	-0.034	-1.271	-0.586	-2.460
Pulse	5	1.372	1.757	0.206	0.669	-0.015	-0.779	-0.282	-1.791
Tuber	5	2.115	2.803	0.426	1.659	-0.024	-1.669	-0.406	-2.706
Cocoa	4	8.094	0.965	0.912	1.698	-0.035	-1.005	-0.646	-0.908
Cassava	4	1.022	2.925	0.636	2.166	-0.042	-2.421	-0.498	-2.995
Cowpea	5	1.036	2.040	0.272	0.908	-0.017	-0.940	-0.351	-2.148
Maize	4	1.398	2.506	0.678	1.932	-0.059	-2.527	-0.446	-0.504

continued next page

Table B3 Continued

Area series									
Series	K	μ	t-stat	\bar{a}	t-stat	\hat{a}	t-stat	\acute{a}	t-stat
Nation	4	4.496	3.579	0.060	0.579	0.013	2.785	-0.283	-3.603
Export	4	2.632	2.741	0.059	1.303	0.008	2.705	-0.181	-2.819
Grain	4	0.334	1.525	0.295	0.644	-0.034	-1.771	-0.686	-2.460
Pulse	5	2.197	1.792	0.212	1.566	0.001	0.906	-0.165	-1.884
Tuber	5	2.151	1.374	0.086	1.151	0.006	0.721	-0.153	-1.339
Cocoa	5	-12.18	-2.623	0.002	0.080	0.005	0.253	-0.905	-2.610
Cassava	4	4.869	2.583	0.084	0.959	0.010	0.930	-0.282	-1.696
Cowpea	4	2.147	1.794	0.128	0.878	0.011	1.284	-0.165	-1.917
Maize	4	4.456	2.398	0.248	0.823	0.014	1.274	-0.335	-2.367

Table B4: Results of co-integration test

Relationship	Trace	ADF/EG	Eigen value
ALQ, ALP, ALRER, T	-3.937**	14.23*	13.08*
ELQ, ELP, ELRER, T	-4.452**	42.61*	39.86*
GLA, GLP, GLRER, T	-4.128**	15.13	14.15
PLA, PLP, PLRER, T	-4.641**	19.58*	18.31*
TLA, PLP, PLRER, T	-4.068**	15.47	14.47
COLA, COLP, COLRER, T	-3.359*	27.26**	25.50**
CVLA, CVLP, CVLRER, T	-3.228*	16.86**	15.78**
CWLA, CWLP, CWLRER, T	-3.482*	17.74**	16.60**
MLA, MLP, MLRER, T	-4.059*	18.85	17.63

** , * = indicates significant at 1% and 5% levels, respectively

Appendix C: Growth rate and price series

Figure C1: Growth rate of total agricultural price series

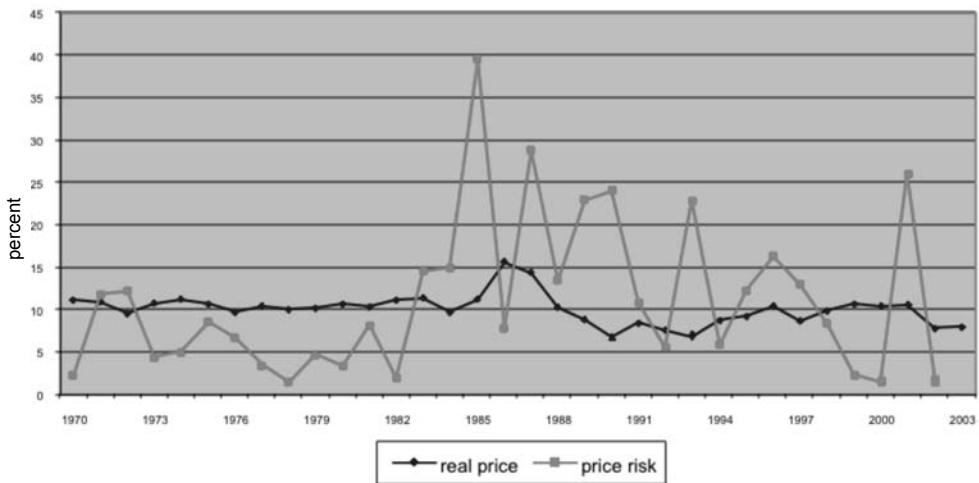


Figure C2: Export crops' price series

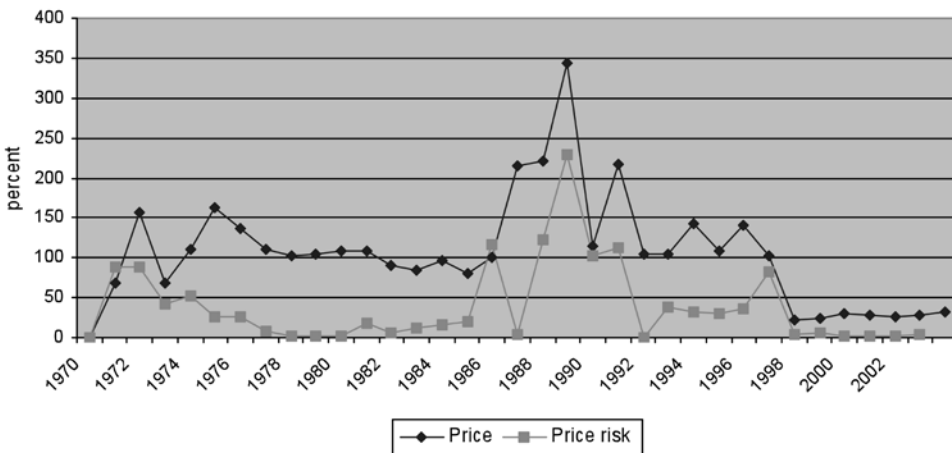


Figure C3: Growth rate of grains' price series

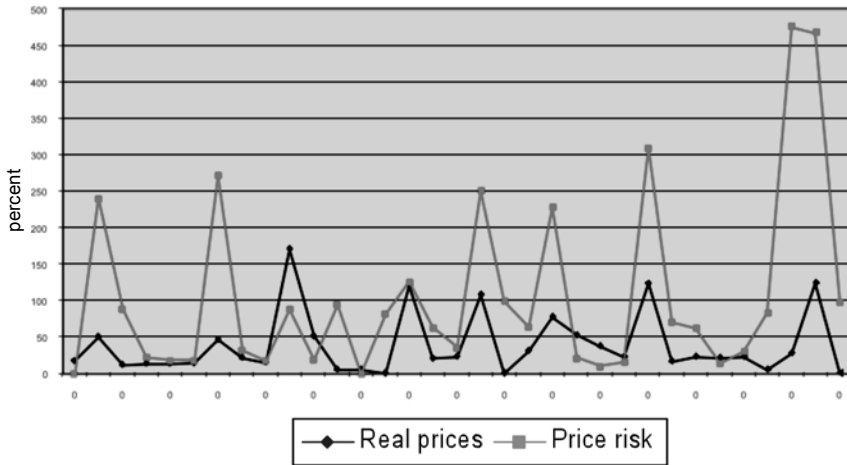


Figure C4: Pulse Price Series

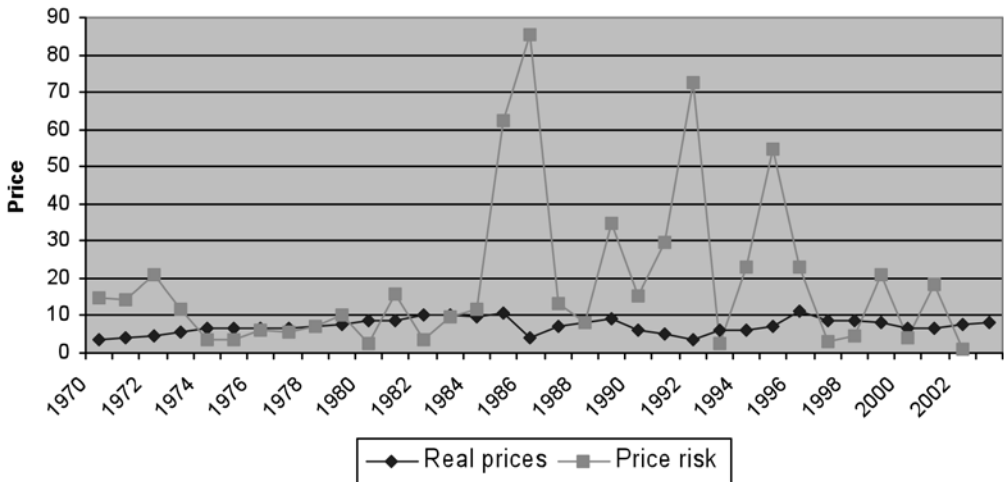


Figure C5: Tuber price series

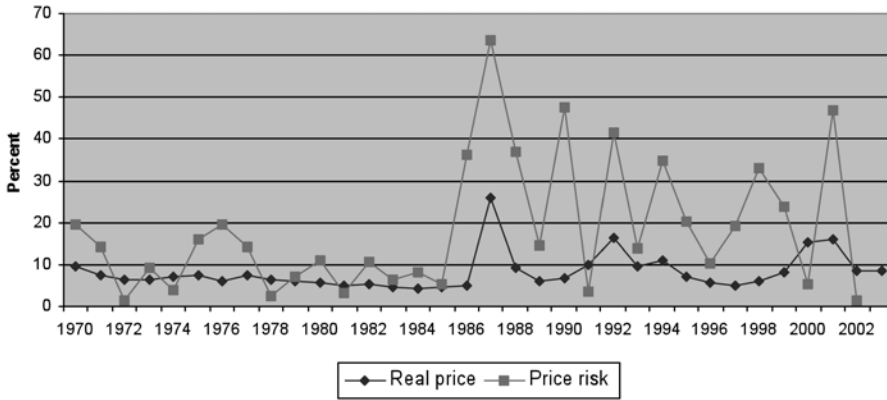


Figure C6: Growth rate of total agricultural crop output, yield and sown area

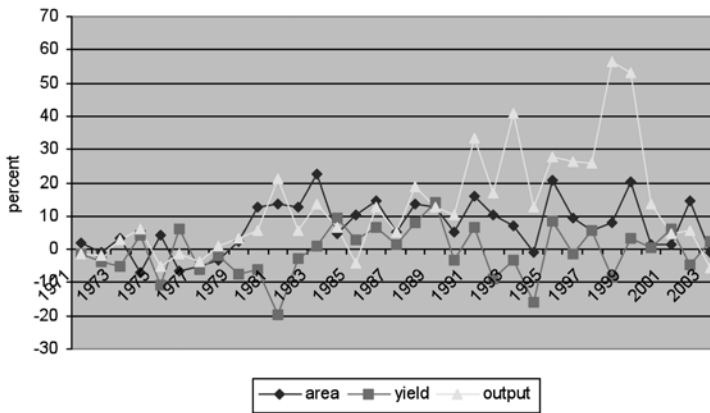


Figure C7: Growth rate of pulse output, sown area and yield

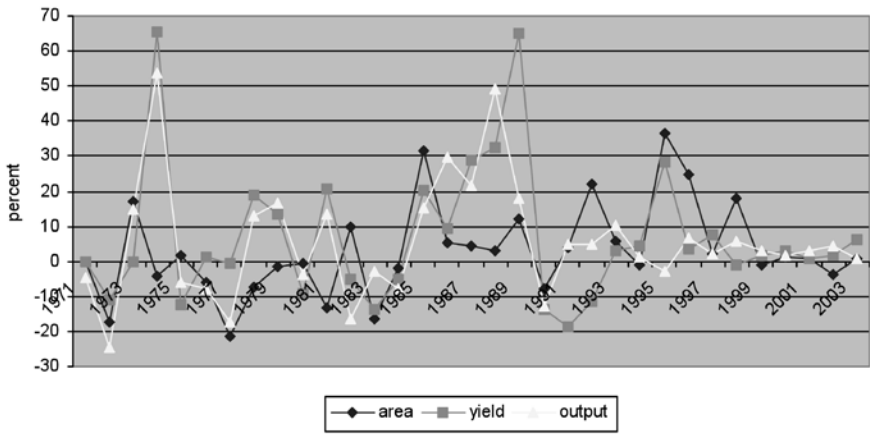


Figure C8: Growth rate of tuber output, yield and sown area

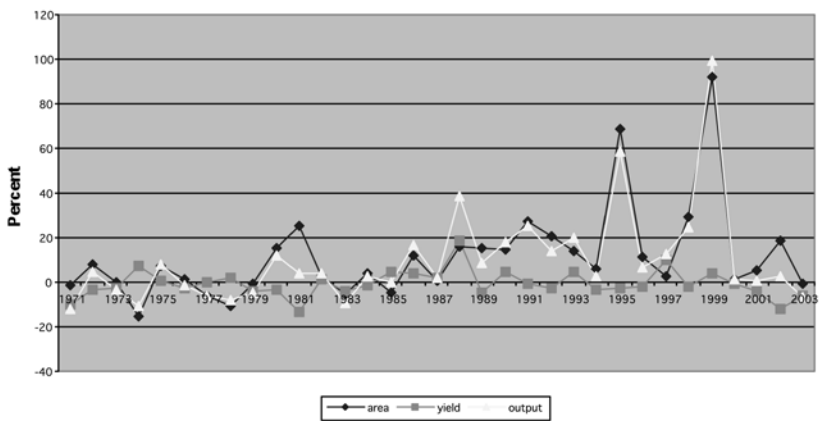


Figure C9: Export crop growth rate of area, yield and output

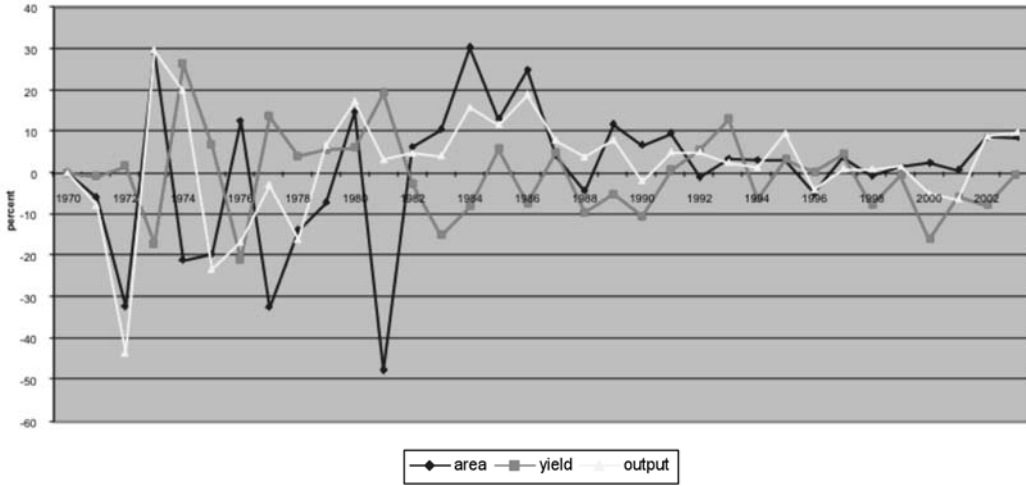
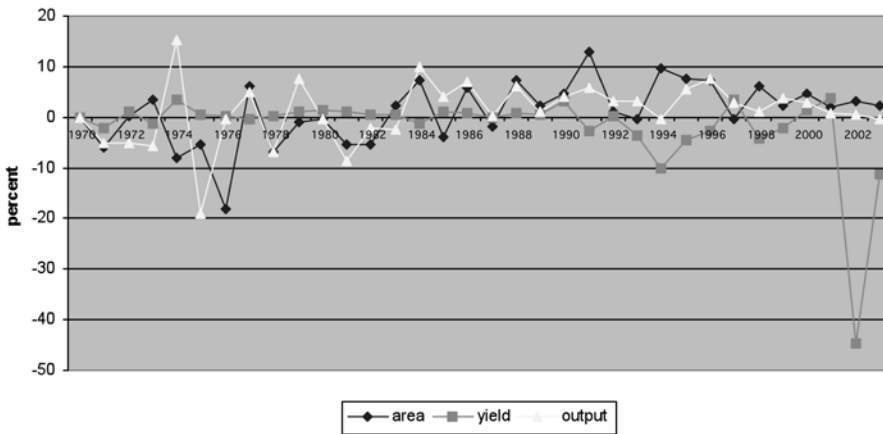


Figure C10: Export crops growth rate of area, yield and output



Appendix D: Modelling of production response

Table D1: ADL modelling of aggregate production response (with price risk)

Variable	coefficient	Std error	t-value	t-prob.
ALQt-2	0.247	0.116	2.135	0.043
ALPt-2	0.094	0.034	2.749	0.011
ALRERt-2	0.070	0.023	3.085	0.005
ALW	-0.951	0.445	-2.139	0.042
D*ALW	-0.902	0.452	-1.995	0.057
D*ALP	0.132	0.048	2.753	0.011

R2 = 0.50 S = 0.052 DW = 1.87 SC = -5.594 HQ = -5.721
 FPE = 0.003 AIC = -5.524 RSS = 0.057 for 6 variables and 30 observations
 Source: Data analysis 2006.

Table D2: Error correction estimates of aggregate production response (without risk)

Variable	coefficient	Std error	t-value	t-prob.
ALQt-2	0.257	0.185	1.392	0.178
ALP	0.304	0.120	2.536	0.019
ALRER	-0.010	0.016	0.634	0.533
ALRERt-1	0.014	0.013	1.068	0.297
ALRERt-2	0.024	0.016	1.468	0.156
D	0.035	0.017	2.070	0.050
D*ALP	0.256	0.126	2.027	0.055
ECM	-0.007	0.124	-0.055	0.956

R2 = 0.65 S = 0.046 DW = 1.63 SC = -5.579 HQ = -5.833
 FPE = 0.003 AIC = -5.592 RSS = 0.045 for 8 variables and 30 observations
 Source: Data Analysis 2006

Table D3: ADL modelling of export crops' production response (with price risk)

Variable	coefficient	Std error	t-value	t-prob.
ELQt-2	-0.554	0.221	-3.041	0.006
ELQt-2	-0.224	0.194	-1.153	0.251
ELPt-1	0.024	0.036	0.557	0.512
ELRERt-1	0.042	0.020	2.054	0.051
ELRERt-2	0.058	0.032	2.099	0.048
ELWt-2	-0.045	0.034	-1.352	0.190
D*ELP	0.087	0.046	1.917	0.058

R2 = 0.42 S = 0.073 DW = 2.29 SC = -4.694 HQ = -4.921
 FPE = 0.006 AIC = -5.024 RSS = 0.117 for 7 variables and 29 observations
 Source: Data Analysis 2006

Table D4: Error correction estimates of export production response (without price risk)

Variable	coefficient	Std error	t-value	t-prob.
ELQt-1	-0.074	0.184	-2.572	0.016
ELPt-1	0.013	0.036	0.358	0.715
ELRERt-1	0.040	0.021	1.914	0.056
ELRERt-2	0.034	0.024	1.393	0.176
D*ELP	0.055	0.041	1.355	0.188
ECMt-2	-0.246	0.199	-1.239	0.228

R2 = 0.35 S = 0.074 DW = 2.29 SC = -4.807 HQ = -4.969
 FPE = 0.006 AIC = -5.043 RSS = 0.133 for 5 variables and 29 observations
 Source: Data Analysis 2006.

Table D5: ADL modelling of grain acreage response (with price risk)

Variable	coefficient	Std error	t-value	t-prob.
GLAt-3	0.342	0.132	2.588	0.018
GLP	0.391	0.092	4.251	0.000
GLPt-4	0.176	0.052	2.874	0.009
GLRER	0.141	0.052	2.252	0.035
GLRERt-3	0.093	0.048	1.952	0.055
GLWt-2	0.183	0.072	2.521	0.020
GLWt-3	0.189	0.056	2.845	0.010
D*GLP	-0.271	0.110	-2.453	0.023
D*GLW	0.218	0.121	1.801	0.086

R2 = 0.51 S = 0.110 DW = 2.17 SC = -3.714 HQ = -4.006
 FPE = 0.015 AIC = -4.139 RSS = 0.248 for 9 variables and 29 observations
 Source: Data analysis 2006.

Table D6: ADL modelling of grain acreage response (without price risk)

Variable	coefficient	Std error	t-value	t-prob.
GLAt-3	0.336	0.179	1.880	0.074
GLP	0.254	0.099	2.549	0.018
GLPt-4	0.121	0.056	1.832	0.081
GLRER	0.019	0.057	0.744	0.735
GLRERt-3	0.059	0.050	1.175	0.253
D	-0.135	0.098	-1.381	0.182
D*GLP	-0.238	0.131	-1.817	0.083
T	0.007	0.003	2.125	0.046

R2 = 0.40 S = 0.135 DW = 1.86 SC = -3.397 HQ = -3.556
 FPE = 0.233 AIC = -3.775 RSS = 0.248 for 8 variables and 29 observations
 Source: Data analysis 2006.

Table D7: ADL modelling of roots & tubers acreage response (with price risk)

Variable	coefficient	Std error	t-value	t-prob.
TLAt-3	-0.140	0.149	-0.941	0.356
TLPt-2	0.107	0.064	1.667	0.108
TRERt-2	-0.108	0.041	-2.608	0.015
TLWt-2	0.033	0.062	0.523	0.061
D	0.090	0.022	4.166	0.000

R2 = 0.56 S = 0.078 DW = 1.63 SC = -4.715 HQ = -4.876
 FPE = 0.007 AIC = -4.950 RSS = 0.145 for 5 variables and 29 observations
 Source: Data analysis 2006.

Table D8: ADL modelling of roots & tubers acreage response (without price risk)

Variable	coefficient	Std error	t-value	t-prob.
TLAt-3	-0.121	0.123	-0.789	0.438
TLPt-2	0.085	0.046	1.862	0.075
TRERt-2	-0.118	0.041	-2.885	0.008
D	0.136	0.051	2.682	0.013
D*TLP	0.014	0.051	0.272	0.788
Trend	-0.002	0.002	-0.930	0.362

R2 = 0.57 S = 0.078 DW = 1.65 SC = -4.628 HQ = -4.822
FPE = 0.007 AIC = -4.911 RSS = 0.132 for 6 variables and 29 observations
Source: Data analysis 2006.

Table D9: ADL modelling of pulse acreage response (with price risk)

Variable	coefficient	Std error	t-value	t-prob.
PLAt-2	-0.328	0.172	-1.907	0.070
PLAt-4	-0.280	0.151	-1.858	0.078
PLPt-2	0.151	0.081	1.875	0.075
PLRERt-3	-0.136	0.051	-2.672	0.014
PLW	-12.753	4.963	-2.570	0.014
D	0.389	0.082	4.728	0.00

R2 = 0.53 S = 0.128 DW = 2.131 SC = -3.500 HQ = -3.759
FPE = 0.021 AIC = -3.877 RSS = 0.346 for 6 variables and 28 observations
Source: Data analysis 2006.

Table D10: Error correction estimate of pulse acreage response (without price risk)

Variable	coefficient	Std error	t-value	t-prob.
PLAt-1	-0.637	0.512	-1.244	0.227
PLAt-2	0.358	0.198	1.857	0.077
PLPt-2	0.150	0.080	1.876	0.074
PLRERt-3	-0.128	0.055	-2.302	0.031
D	0.340	0.107	3.176	0.004
D*PLP	-0.017	0.193	-1.857	0.077
ECMt-2	-0.053	0.512	-0.104	0.918

R2 = 0.45 S = 0.144 DW = 2.14 SC = -3.282 HQ = -3.536
FPE = 0.026 AIC = -3.655 RSS = 0.455 for 7 variables and 31 observations
Source: Data analysis 2006.

Table D11: ADL modelling of cocoa acreage response (with price risk)

Variable	coefficient	Std error	t-value	t-prob.
COLAt-4	-2.065	0.341	-6.045	0.000
COLPt-4	0.011	0.007	1.546	0.136
COLRERt-1	-0.024	0.006	-3.512	0.002
COLWt-1	-0.005	0.004	-1.275	0.215
D	0.137	0.028	4.863	0.000
D*COLP	-0.022	0.007	-3.296	0.032

R2 = 0.79 S = 0.027 DW = 1.69 SC = -6.732 HQ = -6.926
FPE = 0.0009 AIC = -7.015 RSS = 0.172 for 6 variables and 29 observations
Source: Data analysis 2006.

Table D12: Error correction estimates of cocoa acreage response (without price risk)

Variable	coefficient	Std error	t-value	t-prob.
COLAt-1	3.213	0.430	7.464	0.000
COLAt-4	-2.238	0.322	-0.953	0.000
COLPt-1	-0.007	0.009	-0.774	0.447
COLPt-4	0.006	0.007	0.817	0.442
COLRERt-1	0.006	0.006	0.882	0.387
ECMt-1	-3.379	0.453	-7.461	0.000

R2 = 0.82 S = 0.025 DW = 1.61 SC = -6.875 HQ = -7.069
 FPE = 0.0007 AIC = -7.158 RSS = 0.149 for 6 variables and 29 observations
 Source: Data analysis 2006.

Table D13: ADL modelling of cassava acreage response (with price risk)

Variable	coefficient	Std error	t-value	t-prob.
CVLAt-1	-0.367	0.149	-2.468	0.021
CVLPt-1	0.075	0.039	1.944	0.064
CVLRERt-1	0.025	0.025	0.977	0.338
CVLWt-2	0.170	0.053	3.234	0.004
D	0.136	0.051	2.682	0.013
D*CVLP	0.014	0.051	0.272	0.788
Trend	-0.003	0.002	-1.482	0.151

R2 = 0.62 S = 0.078 DW = 2.08 SC = -4.595 HQ = -4.813
 FPE = 0.0007 AIC = -4.919 RSS = 0.144 for 7 variables and 31 observations
 Source: Data analysis 2006.

Table D14: Error correction estimates of cassava acreage response (without price risk)

Variable	coefficient	Std error	t-value	t-prob.
CVAt-1	-0.032	0.252	-0.127	0.900
CVLPt-1	-0.006	0.076	-0.080	0.937
CVLPt-2	0.140	0.042	3.279	0.003
CVLRERt-1	0.034	0.029	1.175	0.252
D	0.077	0.028	2.737	0.012
D*CVLP	0.076	0.050	1.532	0.138
ECMt-1	-0.589	0.414	1.421	0.168

R2 = 0.53 S = 0.086 DW = 2.33 SC = -4.374 HQ = -4.592
 FPE = 0.009 AIC = -4.697 RSS = 0.180 for 7 variables and 31 observations
 Source: Data analysis 2006.

Table D15: ADL modelling of cowpea acreage response (with price risk)

Variable	coefficient	Std error	t-value	t-prob.
CWLAt-1	-0.555	0.128	-3.641	0.003
CWLAt-2	-0.249	0.178	-1.398	0.182
CWLAt-4	-0.252	0.187	-1.348	0.198
CWLPt-1	-0.025	0.097	-0.258	0.800
CWLPt-2	0.649	0.272	2.383	0.038
CWLPt-3	0.921	0.282	3.264	0.005
CWRERt-1	-0.023	0.056	-0.422	0.679

continued next page

Table D15 Continued

Variable	coefficient	Std error	t-value	t-prob.
CWRERt-3	-0.116	0.062	-1.873	0.081
CWRERt-4	-0.202	0.065	-3.123	0.007
CLWt-2	0.234	0.151	1.453	0.167
CLWt-3	0.533	0.180	2.959	0.009
D	0.417	0.144	2.898	0.011
Trend	0.009	0.007	1.338	0.201

R² = 0.63 S = 0.144 DW = 2.09 SC = -2.907 HQ = -3.361
FPE = 0.031 AIC = -3.568 RSS = 0.312 for 14 variables and 29 observations
Source: Data analysis 2006.

Table D16: Error correction estimates of cowpea acreage response (without price risk)

Variable	coefficient	Std error	t-value	t-prob.
CVLAt-2	-0.357	0.197	-1.812	0.087
CVLP	0.113	0.758	0.149	0.883
CVLPt-2	0.125	0.104	1.198	0.244
CWLREt-3	-0.058	0.055	-1.057	0.302
D	0.197	0.082	2.419	0.024
ECMt-1	-0.120	0.201	-0.595	0.558

R² = 0.46 S = 0.171 DW = 2.26 SC = -2.930 HQ = -3.185
FPE = 0.037 AIC = -3.304 RSS = 0.646 for 6 variables and 29 observations.
Source: Data analysis 2006.

Table D17: ADL modelling of maize acreage response (with price risk)

Variable	coefficient	Std error	t-value	t-prob.
MLAt-2	0.324	0.140	2.319	0.030
MLPt-2	0.128	0.095	1.352	0.190
MLRER	0.193	0.056	3.453	0.002
MLW	-0.195	0.376	-3.453	0.004
D	-0.197	0.090	-3.178	0.040
D*MLW	1.154	0.401	2.878	0.009

R² = 0.48 S = 0.192 DW = 2.58 SC = -2.930 HQ = -2.989
FPE = 0.045 AIC = -3.092 RSS = 0.813 for 6 variables and 29 observations
Source: Data analysis 2006.

Table D18: ADL modelling of maize acreage response (without price risk)

Variable	coefficient	Std error	t-value	t-prob.
MLAt-2	0.234	0.194	1.202	0.241
MLPt-1	-0.039	0.146	-0.265	0.793
MLPt-2	0.077	0.119	0.646	0.524
MLREt-2	-0.155	0.082	-1.927	0.066
MLREt-3	0.103	0.082	1.258	0.220
D*MLP	0.234	0.177	1.325	0.198

R² = 0.47 S = 0.264 DW = 1.81 SC = -2.203 HQ = -2.393
FPE = 0.084 AIC = -2.483 RSS = 0.680 for 6 variables and 30 observations
Source: Data analysis 2006.

Appendix E: Results of cusum of square test

Figure E1: National aggregate

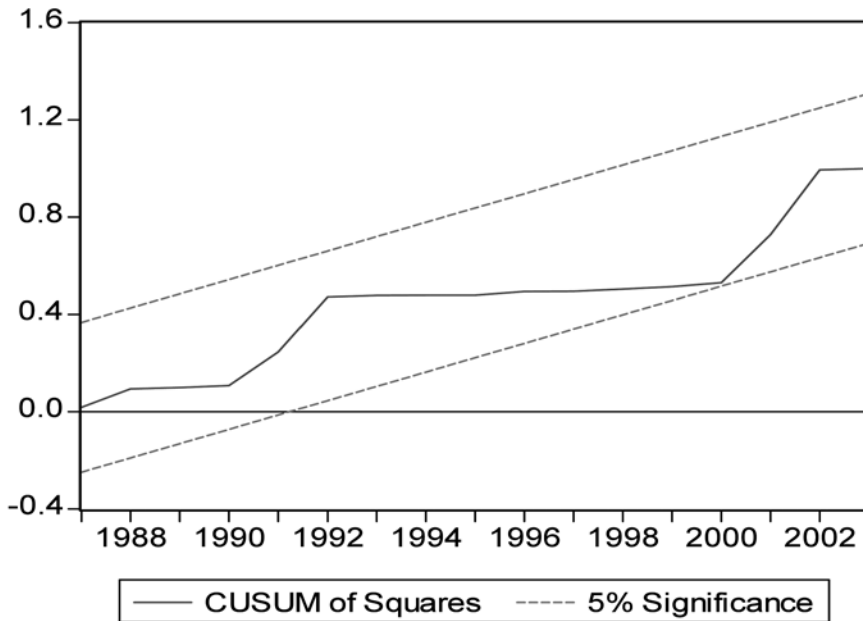


Figure E2: Export

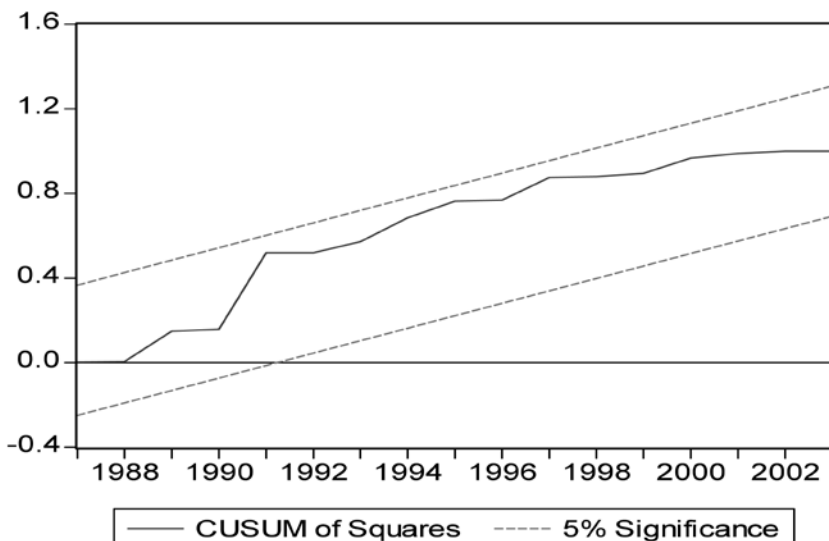


Figure E3: Pulses

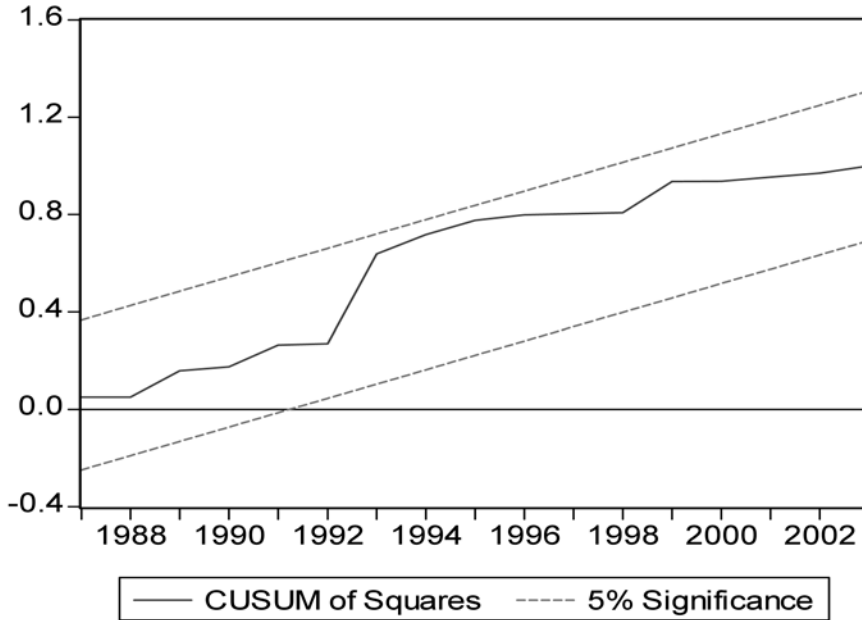


Figure E4: Grain

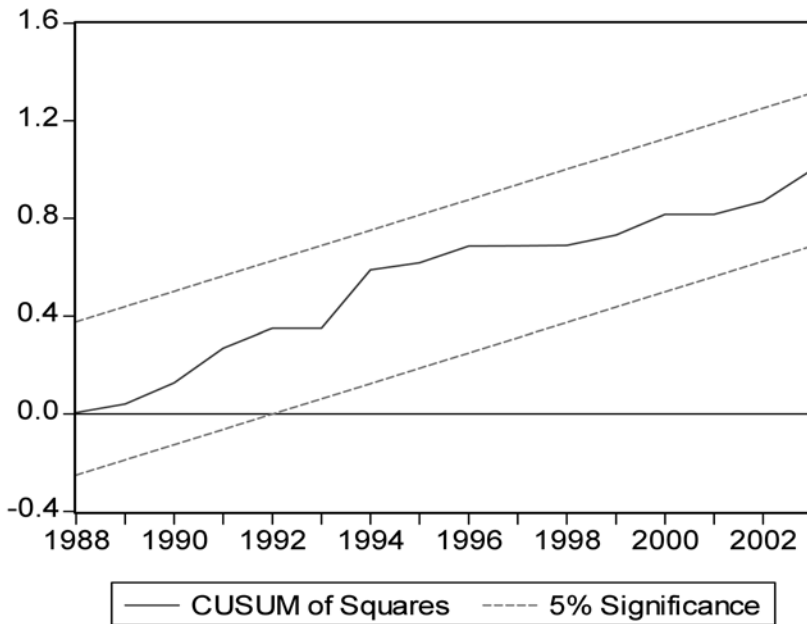


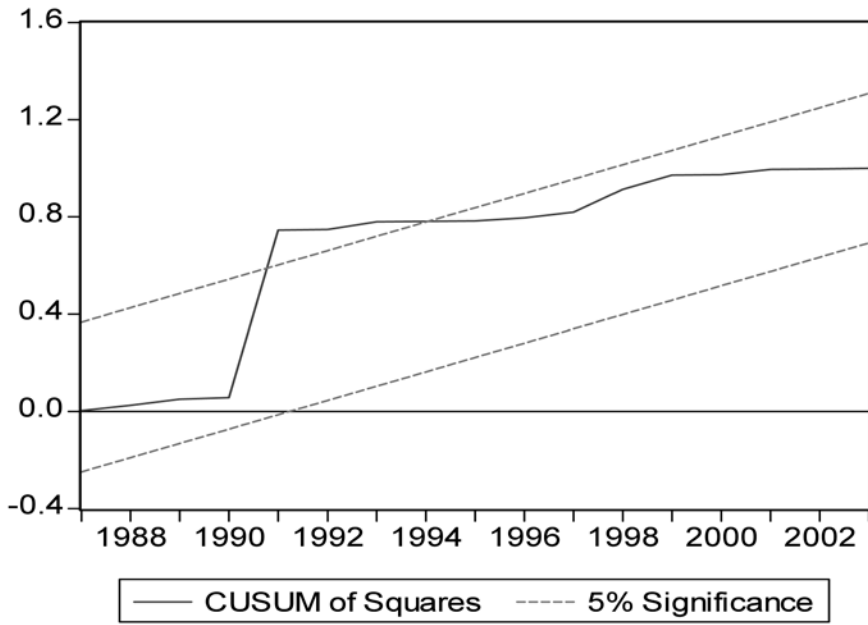
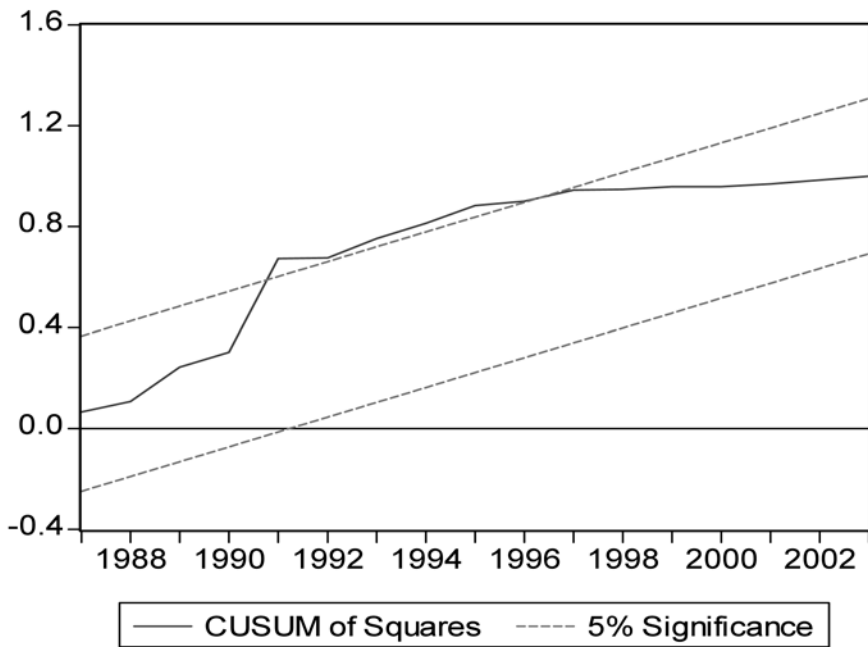
Figure E5: Roots and tubers**Figure E6: Cocoa**

Figure E7: Cassava

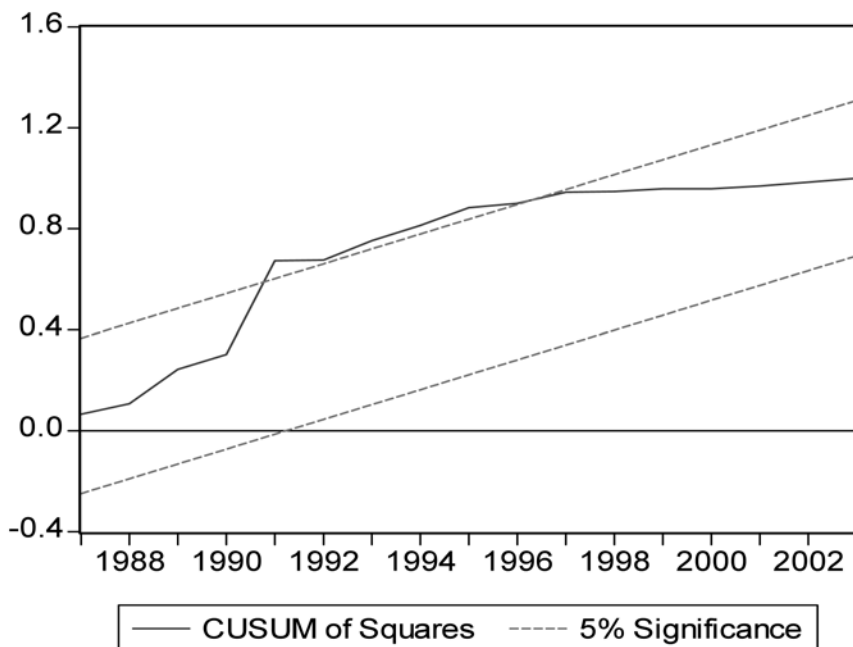


Figure E8: Cowpea

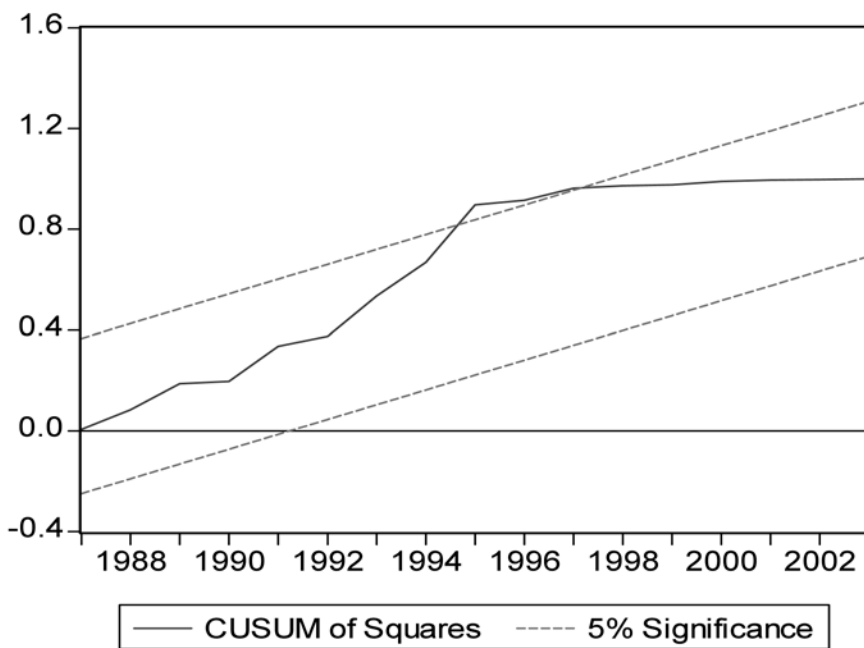
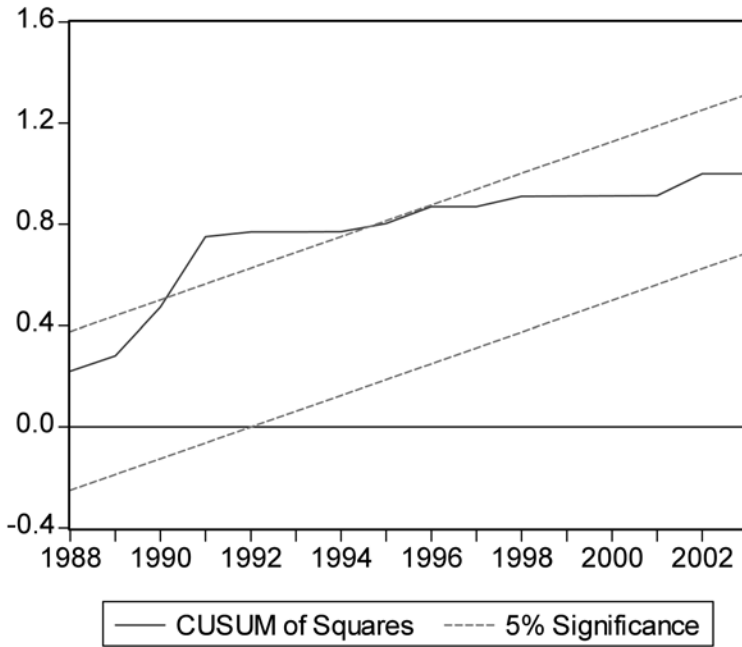


Figure E9: Maize



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