Estimation of the Supply Elasticity of Agricultural Products in Côte d'Ivoire

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Abstract: ***This study examines the origins and likely causes of an asymmetric response of agricultural supply following a shock to prices paid to producers between 1966 and 2011 in Côte d'Ivoire. The results obtained from applying a threshold error-correction model to annual series of prices and cultivated areas show that the asymmetric response mechanism of agricultural supply stems from the existence of costs and intermediaries that limit the supply of agricultural products. Price intervention mechanisms affecting prices paid to producers have led to a weakening of the agricultural supply response following changes in producer prices, as well as to the emergence of asymmetry in the speed of adjustment of agricultural supply- particularly when the price paid to producers is persistently maintained below its equilibrium value. The speed of adjustment appears to depend on the nature of the shock causing the disequilibrium, as cultivated areas tend to converge only weakly, if at all, toward their equilibrium values.***

Keywords: agricultural supply response, price elasticity, Côte d'Ivoire, threshold error correction model, producer prices

1. Introduction

In developing countries such as Côte d'Ivoire, considerable attention is paid to agriculture and the rural world. Indeed, agriculture plays a fundamental role in the economies of developing countries, both in terms of the size of the sector and as an element of development strategy. In low-income countries, agriculture accounts for 32% of GDP (World Bank, 2016). From a welfare perspective, it employs 61% of the labor force in the least developed countries. Rural areas are where absolute poverty is concentrated. Poverty is estimated at 49% in rural areas in developing countries, compared with 32% in urban areas (United Nations, 2017).

With the exception of many countries that have a strong export base in other sectors of the economy (such as oil) or that are well established in the global market for manufactured goods, agriculture has a primary role to play in a development strategy. This role has been extensively described by economic historians (Ohkawa and Rosovsky, 1960) and conceptualized in the classical development literature (Kuznets, 1964), and introduced into the dual economy model (Ranis and Fei, 1961).

Agriculture plays the role of a provider of capital (through land and other taxes, and agricultural savings invested in other activities). The role of agriculture as an effective source of demand for manufactured products has been highlighted through analyses of its effects (Mellor, 1986; Ramasamy, 1991).

Given its important role in the overall response of the economy to reforms and adjustment policies, the agricultural sector helps improve economic performance through the changes it induces in the supply of goods and the demand for factors. The analysis of both supply and demand responses is an essential component of models that seek to explain prices, wages, employment, foreign trade, and government tax revenues.

The literature on the supply elasticity of agricultural products has focused on short-run and long-run responses of individual crops. Most studies have emphasized price elasticity.

Studies analyzing supply responses to price changes are important because prices are the channels through which economic policies affect agricultural variables (supply, production, exports, and income). Variables other than prices also play an important role (such as roads, rural infrastructure, and rainfall).

Estimating the supply elasticity of agricultural products also faces an important methodological problem. The question, therefore, is which methods are the most appropriate.

Binswanger (1989) indicates that the response of aggregate supply to policy changes is more appropriate than the responses of individual crops. However, empirical tests of aggregate supply response are usually problematic.

Oyejide (1990) and Braverman (1989) argue that "pooled data estimators of supply elasticity are less efficient than those based on individual crops." Empirical results from studies indicate that individual crops respond strongly to price factors, often with higher elasticities than aggregate output. The elasticity of individual crops is necessary for policy analysis, particularly when the evaluation of policy effects extends beyond the effects on aggregate output.

The general objective of this study is to estimate the supply elasticity of industrial and food crops taken individually. The specific objective is to examine whether there are asymmetries in price transmission.

As noted above, there are two types of supply elasticity for agricultural products: that of individual agricultural products and the aggregate elasticity. These elasticities can also be estimated in the short run and the long run.

Given that supply elasticity increases over time as the desired reallocation of factors becomes more complete, and as factors of private or public origin become variable in the long run, we assume that long-run supply elasticity is higher than short-run elasticity. In the long run, supply elasticity depends more on fixed factors (Mundlak, 1987). We also assume asymmetry in supply response following changes in prices paid to producers.

This study is divided into four sections: the first section is devoted to a review of the literature on agricultural supply response. The second section presents the methodology adopted and the econometric results. Finally, the fourth section is devoted to the interpretation of the results and the formulation of recommendations.

2. Literature Review

Numerous studies have attempted to estimate the supply response of agricultural products. The sensitivity of supply elasticity depends on the choice of the functional form of the production function, which is largely arbitrary. Bapna, Binswanger, and Quizon (1984), using generalized Leontief models and the normalized quadratic model, estimated a cropping system for the Semeride zone in India using time-series data from 93 districts. The production system includes five crops (wheat, sorghum, other coarse grains, and peas); three variable inputs (fertilizer, labor, and oxen); and five fixed factors that are not controlled by farmers (rainfall, extent of irrigation, road density, and market regulation density). These authors show that supply response elasticities are not constant but depend on sample values of prices and quantities. Moreover, five of the six elasticities have the expected sign: positive for output and negative for inputs. Fertilizer elasticity has the wrong sign but is not significantly different from zero. In addition, cross-price elasticities in such a system do not have a clearly anticipated sign. Finally, the most interesting result of this analysis is that the role of non-price factors, particularly public goods such as road density, is significant.

Fulginiti and Perrin (1990) estimated a translog model of the agricultural sector in Argentina using long-term time-series data (1940–1980). They consider seven crops, three inputs (capital, labor, and fertilizer), and fixed factors. Six of the seven crops have high cross-price elasticities ranging between 0.7 and 1.5. Out of 21 cross-price elasticities, 15 are positive, indicating a complementary relationship among goods.

Using the approach of Bapna, Binswanger, and Quizon, Evenson (1983) estimated short- and long-run agricultural supply responses. In many cases, long-run elasticity is, as expected, substantially higher than short-run elasticity.

Other alternative approaches, such as those of Debertin (1986) and Heathfield and Wibe (1987), estimate supply elasticity using Cobb- Douglas, translog, and generalized power functions with cross-sectional data. The elasticities derived from these models are long-run in nature, as they assume full reallocation of all factors and correct price expectations by farmers, while partial adjustment and adaptive expectations are not taken into account.

Another approach consists of using linear programming by maximizing the profit function while incorporating effective constraints. Supply elasticity is derived through parametric programming from optimal quantities as prices vary.

Nerlove (1956, 1958), taking expectations and partial adjustments into account, developed a model integrating these dynamic processes.

Scandizzo and Bruce (1980) used the Nerlovian model to estimate supply response for 45 countries and 10 crops. In general, short-run elasticity ranges between 0 and 0.8, while long-run elasticity lies between 0.3 and 1.2 (Rao, 1992).

Rosemary (2003) estimated a tobacco supply function in Zimbabwe using a modified Nerlovian model. Short-run elasticity is 0.34 and long-run elasticity is 0.81. Although these elasticities are positive, supply is in fact inelastic, indicating that Zimbabwean farmers are not very responsive to price changes.

Askari and Cummings (1976) and other authors attempted to identify reasons why price elasticity varies across countries and commodities. Their research and other studies point to the following issues: high prices, declining yield risks (Behrman, 1968; Just, 1977), and market failure for alternative crops.

To demonstrate heterogeneity in supply response across countries and regions, Ben Shepherd (2006) used Kalman filters to estimate a structural cotton supply model. The results show that parameters are unstable and need to be adjusted accordingly.

At the aggregate level, supply response elasticity estimated using the Nerlovian model yields short-run elasticities between 0.1 and 0.3 and long-run elasticities between 0.4 and 0.5. It should be noted that the Nerlovian approach tends to overestimate long-run supply response. This is due to failure to properly specify fixed factors or to account for the elasticity of supply response of the factors themselves to prices (Mundlak, 1985).

Cuddihy (1980) conducted a study on supply response under price controls for five major crops in Egyptian agriculture. One-third of the estimated coefficients are significantly different from zero at the 5% level, and the R^2 indicates that a large share of the observed variation in cultivated areas is explained by the model. An interesting aspect of Cuddihy's model is that, unlike many other studies where crops are considered in isolation, the responses of major crops are estimated jointly, allowing interactions among them to be examined. However, these results face several problems, likely reflecting the fact that resource allocation in Egyptian agriculture is characterized by strong government intervention.

Adaptive expectation models have been applied in specialized supply response models that take into account oxen and three crops. Oxen constitute both capital and a product. The structural model predicts that, in both the short and long run, elasticity resulting from an increase in livestock prices would be negative (Jarvis, 1974). However, this is not a strong conclusion, as slight changes in model specification can lead to a positive short-run supply response. Empirically, both negative and positive short-run supply responses have frequently been obtained, often with insignificant coefficients (Nelson and Spreen, 1978; Antonovitz and Green, 1990).

In a study on Brazilian coffee, Wickens and Greenfield (1973) developed a structural model with three equations: a production function, an investment function, and a supply response equation. The reduced form of the supply function derived from the structural model was estimated and shows the importance of lags in tree supply compared to cultivated land.

For the analysis of rubber supply in Sri Lanka, Hartley, Nerlove, and Peters (1987) focused on uprooting and replanting trees, as opposed to new plantations as in the previous study. Their results show a strong and positive response of replanted trees to variations in expected prices and generally a non-significant response to current prices.

Chavas, Pope, and Kao (1983) find that price support programs better explain corn supply response in the United States, while Gardner (1976) shows that future prices are a good substitute for spot prices lagged by one year. However, future prices do not capture all government decisions.

Recent studies using error correction models (ECM) have quantified agricultural supply responses. Hallam and Zanouli (1992), Townsend and Thirtle (1994), Abdulai and Rieder (1995), and Townsend (1996) used cointegration and error correction models to estimate supply response for individual commodities.

In the case of Tanzania, McKay, Morrissey, and Vaillant (1997) showed that agricultural supply response is higher when the agricultural sector is sensitive to price liberalization. Long-run elasticity for food crops is nearly unity, while short-run response is 0.35.

Alemu, Oosthuizen, and Van Schalkwyk (2003) estimated the supply response of Ethiopian wheat, maize, and sorghum producers using ECM. They show that supply response is positively affected by own prices, negatively by substitute crop prices, structural changes in exchange rate policies, and the occurrence of natural disasters. Long-run price elasticities for all crops are significant, whereas, except for maize, short-run price elasticities are not significant. The magnitude and significance of long-run elasticity, compared with the weakness and insignificance of short-run elasticities, are attributed to factors such as structural constraints, supply theory, and the belief that farmers respond only when they are confident that price changes are permanent.

The existing literature has provided a wide range of estimates for supply elasticities. Henneberry and Tweeten (1991) examined agricultural supply response in developed and developing countries, aiming to understand the causal factors behind the diversity of estimates. They show that estimated elasticities vary according to methodology, time coverage, price variable definition, and the type of data used.

Russo et al. (2008) provide estimates of cross-price and income demand elasticities and price supply elasticities for various Californian products. Flexible functional forms- the Box–Cox specification, a system of demand equations, and partial adjustment models- are used to model supply. These models provide good approximations for obtaining elasticity estimates. The six selected products represent the most valuable crops in California: almonds, walnuts, alfalfa, cotton, rice, and tomatoes (fresh and processed). All estimated price demand elasticities are inelastic, and income elasticities are generally below one. On the supply side, all short-run price elasticities are inelastic, while long-run price elasticities are higher than their short-run counterparts. Long-run supply elasticities for cotton, almonds, and alfalfa exceed one. Policymakers can use these estimates to assess changes in consumer and producer welfare in response to policy and economic changes.

Santeramo (2014) estimated global supply response for major agricultural products. The results reveal that higher producer prices encourage increased global crop supply, while producer price volatility has a different effect. Depending on the crop, price supply elasticities range approximately from 0.05 to 0.35. The results suggest that the price–risk ratio of production is negatively correlated with harvests, implying that farmers reallocate land, other inputs, and yields by increasing investments in favor of less productive crops. Recent producer price volatility appears to significantly reduce wheat production and, to a lesser extent, rice production.

Schneider, Eric B. (2014) challenges the consensus in the literature (Stone, 2001, 2005) that medieval manor managers were price-sensitive in their production decisions. Using prices and planted areas of wheat, barley, and oats from manors owned by the Bishop of Winchester between 1325 and 1370, he estimates price supply elasticities overall and for each individual manor. Aggregate price elasticities of supply for wheat, barley, and oats were rarely statistically significant, and when they were- both in developing and developed countries- they were very small.

Haile et al. (2015) adopt a dynamic panel supply model to analyze global cropland response to price changes and price volatility for four crops (maize, soybeans, wheat, and rice). They estimate the model using pooled generalized instrumental variables through the generalized method of moments (GMM) developed by Arellano and Bond (1991) and Blundell and Bond (1998). Like other panel estimators, GMM estimators account only for intercept heterogeneity across panel units (countries). GMM estimators use lagged levels as instrumental variables. However, when all coefficients differ across countries, lagged levels are not valid instruments. Consequently, GMM estimates are inconsistent. It is therefore important to examine supply response to price changes using econometric methods that account for both coefficient heterogeneity and the non-stationary nature of variables in a dynamic panel framework.

Several studies have focused on estimating farmers' supply response in sub-Saharan Africa. This literature has used a variety of approaches and has generally concluded that price supply elasticities are low or very low. However, only a few analyses go beyond estimating aggregate supply response for the sector as a whole or for specific crop cases. In most cases, data scarcity- particularly on producer prices- has been the main limiting factor. Magrini et al. (2016) revisit this issue by focusing on the supply response of staple food crops in selected sub-Saharan African countries (SSA). They use an innovative dataset recently developed by the FAO, the “Monitoring and Analysing Food and Agricultural Policies” (MAFAP) database, which provides prices at the producer, wholesale, and border levels for selected value chains. Using dynamic panel techniques, they measure and test how area, production, and yields respond to price signals and other non-price factors in relation to the recent price crisis (2005–2013). They find that farmers producing staple food crops respond to price signals, albeit with limited intensity. Moreover, their results suggest that direct price incentives arising from border protection and government intervention in domestic markets matter; border price shocks are more important than macroeconomic policies in influencing farmers’ decisions. They also show that omitting marketing costs in the supply response function leads to underestimation of price elasticity, whereas using wholesale prices instead of producer prices as proxies leads to overestimation of price elasticity

3. Methodology, Econometric Estimation, and Interpretation of Results

3.1 Methodological Approach

In this study, the methodology used is cointegration and the error correction model (ECM). These methods make it possible to address the problem of spurious regressions, provide consistent estimators, and distinguish between short-run and long-run elasticities that satisfy the properties of classical regression procedures. This is because all variables in an error correction model are integrated of order zero, I(0). Spurious regressions, inconsistency, and the failure to distinguish between short-run and long-run elasticities are the major problems associated with traditional adaptive expectations models and partial adjustment models (Hallam and Zanoli, 1993; McKay et al., 1998).

Cointegration and error correction models have been used in the analysis of supply response in the agricultural sector in other countries by many researchers, such as Townsend (1997), Schimmelpfenning et al. (1996), and Townsend and Thirtle (1994). The use of cointegration techniques makes it possible to establish long-run equilibrium relationships among variables. For this purpose, the Johansen test is employed.

3.2 The Engle and Granger Error Correction Model

First, the variables considered individually must be integrated of the same order. Second, the linear combination of these variables must be integrated of a lower order than that of the original variables (Engle and Granger, 1987). In other words, if the variables under consideration are integrated of order one, I(1), for example, the error term of the cointegrating relationship would be integrated of order zero, I(0), implying a temporary deviation between short-run movements of the variables and their long-run equilibrium. The deviation from the long-run equilibrium path is therefore limited, and if cointegration is confirmed, Engle and Granger (1987) show that the variables can be represented within a dynamic error correction structure.

Thus, in this study, as in other similar studies, supply response is modeled in two stages. The unit root test results are reported in Tables 1 and 2 in the appendix.

First, a static cointegrating regression given by Equation (1) is estimated for each crop, and cointegration tests are conducted.

$$S_{ti} = \alpha_i + \lambda_i t + \beta_i P_{ti} + \beta_j P_{tj} + \beta_k P_{tk} + \mu_{ti}$$

Where, $S_{ti}, P_{ti}, P_{tj}, P_{tk}$ are vectors representing, respectively, the area planted to product *i*, the price of product *i*, and the prices of substitute products *j* and *k*. A time trend is introduced. $(\alpha_i + \lambda_i t)$ to account for public infrastructure, rainfall, and fertilizers.

Second, if the null hypothesis of no cointegration is rejected, the lagged residuals from the cointegrating regression are imposed as the error correction term in the error correction model. An example of an ECM is given below:

$$\Delta S_{ti} = \varphi_0 + \varphi_{1i}\Delta P_{ti} + \varphi_{2i}\Delta P_{tj} + \varphi_{3i}\Delta P_{tk} + \lambda(S_{t-1,i} - \alpha_i - \lambda_i t - \beta_i P_{t-1,i} - \beta_j P_{t-1,j} - \beta_k P_{t-1,k}) \quad (2)$$

Where Δ denotes the first difference, λ measures the error correction coefficient.
φ_{1i}, φ_{2i}, φ_{3i} measure the short-run effect on supply, in percentage terms, of a change in the price of a crop (or the short-run price elasticity of supply), while β_i, β_j, and β_k measure the long-run price elasticity of supply.

To test for cointegration, we use the Johansen methodology. The testing procedure is based on the maximum likelihood method, with the advantage of being able to account for several specific features of long-run relationships. In practice, it leads to the computation of the trace statistic and the maximum eigenvalue statistic, which determine the number of cointegrating relationships among the variables (see Table 3 in the appendix).

However, the parameters estimated from the error correction model provide price supply elasticities without indicating how price changes are transmitted to adjustments in cultivated areas. For this purpose, we estimate a threshold error correction model in order to account for the symmetry or asymmetry of price transmission.

3.3 The Threshold Error Correction Model

In the case of standard linear cointegration, the residual series can be described by an autoregressive (AR) model of the form:

$$\mu_t = \rho\mu_{t-1} + \varepsilon_t \quad (3)$$

where ε_t is white noise. In the case of nonlinear cointegration, by contrast, the error correction term is described by a threshold autoregressive (TAR) model, such as:

$$\mu_t = \begin{cases} \rho_1\mu_{t-1} + \varepsilon_{1t} \; si \; \mu_{t-1} \geq \theta \\ \rho_2\mu_{t-1} + \varepsilon_{2t} \; si \; \mu_{t-1} < \theta \end{cases} \quad (4)$$

Enders and Siklos Test
The hypothesis that the error correction term is described by a TAR process can be tested using an asymmetric

cointegration test. Enders and Granger (1998) and Enders and Siklos (2001) modified the standard Dickey–Fuller cointegration test in order to test the hypothesis of a cointegrating relationship between prices without maintaining the assumption of symmetry in long-run adjustment. Indeed, the standard Dickey–Fuller test, which is based on the assumption of symmetric adjustment, may tend to reject the hypothesis of cointegrated series when asymmetry is present in the cointegrating relationship.

As in the standard cointegration test, the asymmetric cointegration test is based on the stationarity of the residual ε_t. For μ_t to be stationary, the following condition must be satisfied: $-2 < (\rho_1, \rho_2) < 0$. If each sequence is stationary, the estimated ρ_1 and ρ_2 follow a multivariate normal distribution, and the test equation is formulated as follows:

$$\Delta\mu_t = I_t \rho_1 \mu_{t-1} + (1 - I_t)\rho_2 \mu_{t-1} + \varepsilon_t \quad (5)$$

where I_t is an indicator variable defined as follows:

$$I_t = \begin{cases} 1 \; si \; \mu_{t-1} \geq \theta \\ 0 \; si \; \mu_{t-1} < \theta \end{cases} \quad (6)$$

The threshold θ is generally unknown, but it can be determined endogenously. The procedure consists of obtaining the residuals from Equation (1) and then sorting them in ascending order. The highest 15% and the lowest 15% of the values are discarded, and the remaining values constitute the set of potential thresholds. The test equation is estimated for each of these potential thresholds. The threshold θ is determined by minimizing the sum of squared residuals of Equation (5).

When the Enders and Siklos test detects the presence of asymmetry in the cointegrating relationship, it becomes possible to estimate an ECM in which the adjustment of cultivated areas depends on the nature of the disequilibria.

4. Interpretation of Results

The empirical analysis is based on a study of eleven agricultural products categorized into four groups: export crops (coffee, cocoa, cotton), cereals (maize, millet, rice, sorghum), fruits (pineapple, banana), and tubers (yam, cassava). Annual data on cultivated areas and prices for these products are available from the FAO website. The series cover the period from 1972 to 2014, yielding 52 observations per variable. Cultivated areas are expressed in hectares and prices in local currency units. Price series are deflated by the consumer price index (base year 2000) available on the World Bank CD-ROM. Both prices and cultivated areas are expressed in logarithms.

The hypotheses are tested following an identical procedure for the eleven variables. The first step consists of testing the statistical properties of the series, estimating the long-run relationship between prices, testing for the existence of a cointegrating relationship using standard methods, and, insofar as cultivated areas and prices are found to be cointegrated, estimating an error correction model. The second step is devoted to the hypothesis of asymmetry in the adjustment of cultivated areas. It first involves estimating a TAR model, from which the asymmetry hypothesis is tested using the Enders and Siklos (2001) method. Subsequently, an ECM that accounts for asymmetry is estimated.

4.1 Unit Root and Cointegration Tests

The unit root tests (Table 1 in the appendix) reveal that all variables are integrated of order one. Indeed, the ADF test statistics are greater than the critical values. By contrast, tests on first differences show that the variables are stationary. The necessary condition for cointegration is demonstrated using the Johansen test. The trace statistics (Table 2 in the appendix) indicate the existence of a cointegrating relationship. The optimal lag length is q=1. This lag length minimizes the information criteria (FPE, SC, AIC, HQ).

4.2 Direct Price Elasticity

The Fisher statistics (Table 1 above) indicate that the models are globally significant, with the exception of the long-run equation for rice. The coefficients of determination (R^2) show a strong association between cultivated areas and agricultural product prices. Four of the eleven long-run direct price elasticities have the expected sign: coffee, yam, cassava, and millet; however, only the elasticity for coffee is statistically significant. The elasticities for fruits, cocoa, sorghum, and rice are negative. This negative sign indicates that a decrease in the price of these crops leads to an increase in cultivated area. Indeed, when prices fall, farmers expand cultivated areas in order to increase output and compensate for income losses due to the price decline.

However, for coffee, yam, and cassava, an increase in the own price has a positive effect on cultivated areas. Specifically, a 1% increase in the own price leads to an increase of 0.20%, 0.06%, and 0.035% in cultivated area, respectively. Nevertheless, only the direct price elasticity for coffee is statistically significant.

4.3 Cross-Price Elasticity

Cross-price elasticity is negative for coffee, yam, millet, and rice, reflecting substitutability between coffee and cocoa, yam and cassava, and rice and maize. For the other crops, cross-price elasticities are positive, indicating a tendency for producers either to reallocate cultivated area between their main crop and competing crops or to cultivate new land. In both cases, cultivated areas increase following a price increase.

The inclusion of a time trend makes it possible to account for phenomena such as rainfall and fertilizer use. These factors, with the exception of the long-run rice equation, have a positive effect on cultivated areas. The hypothesis that long-run elasticities are greater than short-run elasticities is not verified for most crops, which is contrary to expectations. Indeed, the results show that short-run elasticities are higher than long-run elasticities for coffee, banana, yam, cassava, millet, and rice. Overall, in the long run, there is evidence of crop rotation and the sharing of cultivated areas among several crops depending on the prices paid to producers.

4.4 Test of Asymmetry in the Supply Response of Agricultural Products

The Enders and Silkos test was used to examine the hypothesis of asymmetry in the response of agricultural product supply following a price increase. A TAR model was estimated to conduct this test (Table 2). Subsequently, an ECM (Error Correction Model) was estimated to account for the asymmetry.

Table 3 presents the results of the ECM estimation, where the coefficients vary depending on the period. In the case of Côte d'Ivoire, the Wald test applied to the model coefficients indicates that the short-term response is significantly higher after the breakpoint for bananas, coffee, tubers, millet, and sorghum.

Conversely, for pineapples, cocoa, and rice, the short-term response is significantly higher before the breakpoint. Indeed, for these products, the adjustment speed does not appear significantly higher after the breakpoints.

Moreover, the breakpoints for pineapples (2011) on the one hand, and for cotton, rice, and sorghum (1973) on the other hand, do not allow a conclusion of asymmetry in short-term relationships.

In Table 3, it is possible to see for which product the shock is more pronounced and whether the response to correct long-term imbalance occurs before or after the breakpoint. Thus, cultivated areas adjust either downward or upward to correct potential long-term imbalances.

The results of the Enders and Silkos test are presented in Table 3. They allow us to conclude that there is asymmetry in the adjustment speed of cultivated areas following a shock in producer prices. All coefficients are statistically significant.

The Wald test indicates asymmetry in the response to changes in producer prices for certain crops such as bananas, pineapples, yams, cassava, and maize. In contrast, the asymmetry hypothesis is rejected for other crops such as cocoa, coffee, rice, millet, and sorghum.

Overall, this study of agricultural supply response in Côte d'Ivoire highlights crop rotation; the positive long-term impact of fixed factors on the supply response; the increase in cultivated areas for certain crops to compensate for price decreases through higher quantities; and the asymmetry of the supply response following a price shock.

5. Conclusion

This study analyzed the asymmetry of price transmission for the coffee, cocoa, and cotton sectors, as well as for bananas, pineapples, and food crops in Côte d'Ivoire over the period 1972–2024, using the methods of Engel and Granger (1987) and Enders and Silkos (2001). The results show adjustments in cultivated areas following price shocks. These findings indicate different thresholds from zero that define the regimes of agricultural supply adjustment.

A review of several empirical studies reveals costs of increasing cultivated areas and land tenure regulations as the main causes of asymmetric responses of cultivated areas to price shocks. In the case of Côte d'Ivoire, this could explain the weak or almost nonexistent impact of price signals on cultivated areas.

Furthermore, the liberalization of agricultural markets and the dismantling of public marketing agencies for coffee and cocoa are likely to have influenced the transmission of shocks to the supply of these products. In addition, the results show no improvement in the adjustment speed of cultivated areas. In light of this study, interventions in producer prices have weakened the transmission of prices to the supply of agricultural products as approximated by cultivated areas.

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Annexe 1

Table 1 : Estimation des relations de long terme

Variables	Cultures d'exportation					Cultures vivrières					
	Ananas	Banane	Café	Cacao	Coton	Igname	Manioc	Mais	Mil	Sorgho	Riz
Constante	8,56 (4,33)	9,71 (10,93)	17,57 (5,03)	15,83 (11,03)	13,71 (5,16)	10 (13,47)	10,45 (15,05)	10,87 (5,69)	10 (2,42)	10,55 (6,94)	10,41 (4,56)
Trend	0,014 (1,54)	0,012 (3,29)	-0,06 (-0,98)	0,029 (1,38)	0,04 (4,52)	0,04 (8,22)	0,02 (5,67)	-0,01 (-0,54)	0,003 (0,34)	0,015 (2,66)	0,012 (2,63)
logP1	-0,20 (-1,59)	-0,105* (-1,92)	0,20 (3,16)	-0,21 (-2,56)	-0,22 (1,22)	0,006 (-0,07)	0,035 (0,78)	-0,135 (-1,25)	0,067 (0,63)	-0,09 (-0,96)	-0,004 (-0,026)
logP2	0,17 (1,33)	0,07 (1,20)	-0,37 (-3,79)	0,026 (0,42)	0,067 (0,065)	-0,17m (-1,94)	0,09 (2,16)	0,26i (2,67)	-0,33i (-1,90)	0,07r (0,93)	-0,35m (-2,02)
logP3					-0,10 (-0,82)	0,43mi (5,45)		-0,18ma (-1,92)	0,37ma (1,63)		0,52s (2,97)
R^2	0,74	0,75	0,92	0,98	0,97	0,98	0,94	0,93	0,52	0,88	0,36
F-stat	24,50	26,01	99,36	498	230	478	128	67,73	7,20	66,45	4,86

Sources: FOA/ nos calculs sous Eviews ; (.): t de Student

Appendix 2

Table 2: Estimation of the TAR Model (Threshold Autoregressive)

Paramètres	Cultures d'exportation					Cultures vivrières					
	Ananas	Banane	Café	Cacao	Coton	Igname	Manioc	Mais	Mil	Sorgho	Riz
θ	-0,0965	-0,0162	-0,0636	-0,0395	0,1135	0,0249	0,0404	-0,0606	0,0786	0,0846	0,0829
ρ_1	-1,04 (-2,47)	-0,963 (-5,66)	-0,91 (-2,65)	-1,09 (-1,04)	1,20 (6,21)	0,97 (6,68)	-0,136 (-0,57)	-1,93 (-2,73)	-1,27 (-4,78)	-1,21 (-2,61)	-0,94 (-3,87)
ρ_2	-0,75 (-4,18)	-0,62 (-2,045)	-1,04 (-5,38)	-1,105 (-6,11)	O,83 (6,00)	1,15 (11,15)	-1,125 (-6,70)	-0,67 (-4,18)	-0,82 (-3,90)	-0,89 (-5)	-0,70 (-2,94)
F	11,79	18,65	18,07	19,21	29	47.17	22,69	12,47	19,16	16	12,75
Wald	0,41	0,88	0,109	0,0001	2,26	0,94	5,89	2,98	1,79	0,40	0,44

Sources: FOA/ nos calculs sous Eviews ;
(.): t de Student

Appendix 3: Short-Term Model Estimation

Table 3: Estimation of the Short-Term Relationship

Variables	Cultures d'exportation					Cultures vivrières					
	Ananas	Banane	Café	Cacao	Coton	Igname	Manioc	Mais	Mil	Sorgho	Riz
Constante	0,04 (1,96)	0,025 (2,60)	-0,003 (-0,087)	0,04 (3,48)	-0,54 (-0,90)	0,04 (5,63)	0,005 (0,37)	0,02 (1,98)	-0,007 (-0,39)	0,022 (1,31)	0,011 (0,56)
DlogP1	-0,20 (-1,84)	0,09* (1,93)	0,22 (3,13)	-0,19 (-2,45)	-0,23 (-1,52)	0,04 (1,11)	0,037 (0,98)	-0,22 (-1,78)	0,059 (0,64)	-0,063 (-0,67)	0,075 (0,96)
DlogP2	0,13 (1,00)	-0,225 (-4,76)	-0,38 (-485)	0,034 (0,57)	0,04 (0,97)	0,30 (5,08)	0,056 (1,20)	0,40 (6,36)	0,16i (0,92)	-0,005r (-0,07)	0,095m (0,96)
DlogP3					-0,14 (-1,26)			-0,34ma (-4,45)			-0,15s (-1,67)
AR (1)			0,52					-0,55			

			(2,77)					(-3,36)			
λ^+	-0,40 (-1,85)	-1,42 (-3,71)	-0,63 (-2,50)	-0,056 (-0,26)	-0.04 (-2,43)	1,49 (2,35)	0,86 (1,42)	-0,27 (-1,51)	-0,77 (-0,292)	-1,74 (-3,26)	-0,06 (-0,22)
λ^-	0,76 (2,01)	0,40 (0,863)	-0,28 (-0,86)	-0,75 (-2,04)	-085 (-2,51)	-0,42 (-1,77)	-0,47 (-1,65)	1,38 (6,12)	-0,16 (-0,71)	-0,75 (-1,83)	0,29 (1,086)
WALD	6,82	8,48	1,10	2,66	0,15	10,6	6,13	6,81	3,11	2,65	0,79
R^2	0,26	0,56	0,47	0,25	0,33	0,60	0,26	0,66	0,25	0,39	0,12

Sources : FOA/ our calculations under Eviews ; (.) : t de Student