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Food crops, exports, and the short-run policy response of agriculture in Africa

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Abstract

The response of agriculture to changes in relative prices is an important factor in the success of structural adjustment programs in Africa. In this paper I estimate supply functions for total agricultural output, food crops and export crops in 14 African countries for the years 1975 to 1990. Food and export crops are substitutes in production in the short run. Total agricultural output responds negatively to increases in export prices and positively to increases in food prices. A plausible explanation is that as farmers shift resources to export crop production, food supply falls in the short run, while the increase in export supply may take several years to materialize. The exchange rate is significant in explaining both food and export crop production and aggregate agricultural supply, suggesting that the exchange rate is acting as a proxy for excluded macroeconomic variables or that changes in the exchange rate are not passed immediately through to prices. © 2000 Elsevier Science B.V. All rights reserved.

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1. Introduction

In his 1989 review of the effects of price policy on agriculture, Binswanger noted that the aggregate response of agriculture to changes in the price and exchange rate regimes was likely to be low, since the major inputs to agricultural production — land, labor, and capital — are essentially fixed in the short run (Binswanger, 1989). Changes which adjust the relative returns between different crops are likely to shift resources into production of the crop whose relative price rises. In the context of Africa, a continent widely understood to be food-deficient, the substitution of export crop production for food crop production is of par-

ticular concern. Moreover, Africa has seen intensive efforts at structural adjustment in the last several years, aimed at correcting serious exchange rate and current account deficit problems. A by-product of structural adjustment programs is the promotion of export-crop production, as devalued currencies make African products competitive on world markets again. If structural adjustment programs lead to movements along the production possibilities frontier, in which farmers substitute export-crop production for food-crop production, then they will likely have only a limited effect on aggregate agricultural output. On the other hand, if price realignments raise foreign exchange earnings, which are badly needed by most countries in Africa, and do not negatively impact on food production, they can be an invaluable tool in moving Africa into the twenty-first century. In this paper, I examine whether

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food crops and exports crops in Africa are substitutes in production *in the short run*.

Africa is a particularly useful region to study because of widespread economic reform that occurred there in the 1980s, and because of the serious misalignment of exchange rates and prices which precipitated it. Because agriculture represents such a large share of value added in Africa, movements in agricultural output have important macroeconomic implications for most African countries. Improved data on producer prices for several African countries facilitates analysis of aggregate agricultural supply.

In this paper, I utilize a pooled data set covering 14 Sub-Saharan Africa (SSA) countries from 1975 to 1990 to examine the impact of movements in prices and exchange rates on food crop and export crop production in SSA. I utilize two new and unique data sources. Food and export crop price indices were created using price data available in the World Bank's African Development Indicators 1992. In addition, I use data on rainfall constructed by the Famine Early Warning Systems (FEWS).¹ In earlier studies, the influence of weather on supply response is either ignored or measured in a way that leads to biased coefficient estimates. In the African context rainfall is a crucial determinant of agricultural production, and must be modeled carefully.

I find evidence that aggregate agricultural output rises with increases in food prices but falls with increases in export prices in the short run; higher exchange rates are negatively associated with aggregate output. Food crops and export crops are substitutes in production. Empirical results are consistent with the view that shifting resources away from food crop production may lead to lower total agricultural output *in the short run*, since it may take several years for export crops to respond to higher input levels, while food crop production falls immediately.

The organization of the remainder of the paper is as follows. In Section 2, I consider the existing evidence on supply response in Africa. In Section 3, I briefly outline the relationship between the exchange rate and agricultural prices, and outline its importance for applied work. Section 4 discusses estimates of the aggregate agricultural supply function. Section 5 lays

Table 1

Range of estimates for small holder long-run supply elasticities, in Sub-Saharan Africa (Oyejide (1990))

Crops	Low	High
Cocoa	0.32	1.81
Coffee	0.47	1.01
Palm Oil	0.22	0.26
Rubber	0.17	0.24
Cotton		2.44

out the structural econometric model which I estimate, and Section 6 concludes.

2. Supply response in Africa: a brief review

The response of agricultural supply to price movements has been the subject of long and vigorous discussion, going back to Nerlove's classic (1958) treatment of the long-run supply elasticity for corn, cotton and wheat in the US.² Estimates of supply elasticity (short-run and long-run) based on the Nerlove model vary widely from crop to crop and region to region, leading some to argue that the Nerlovian model is inadequate for deriving the long-run response.³ I do not intend to debate the relative merits of the Nerlovian method for obtaining the long-run supply elasticity in the current paper. Following Binswanger (1989), I adopt the view that the long-run policy response of agriculture to structural adjustment may not be discernible with regression analysis, especially in models with the simple lag structures such as those characterizing the Nerlove model. Rather, I ask a more basic question: How does agriculture respond in the *short run* to changes in prices and exchange rates?

Table 1 gives estimated supply response to price for a number of crops and countries.⁴ These estimates vary by as much as 500%, even when attention is restricted to Sub-Saharan Africa. When considering *aggregate* response to price movements, however, it is necessary to consider the essentially fixed nature of a

¹ I am indebted to Graham Farmer of FEWS for making these weather data available.

² For a summary of the literature through the early 1970s, see Askari and Cummings (1977).

³ See, for example, Nerlove (1979), Braulte (1982), Binswanger (1989) and Diebold and Lamb (1996).

⁴ Oyejide (1990).

number of the primary agricultural inputs, especially land, but in many production environments labor as well. Thus, the short-run response of aggregate output to price movements must take account of not only the rise in production of crop A due to an increase in the price of A, but the accompanying decrease in the production of crop B, as resources shift from one crop to another. One method for obtaining the aggregate response of agriculture is to aggregate elasticities from crop-specific models, weighting by the crop's share in total production. Using Nerlovian estimates of supply response for individual crops, Binswanger calculates aggregate supply elasticity as low as 0.05 (Binswanger, p. 234). For countries which produce tree-crops, such as coffee, tea, cocoa and palm oil, the estimated price response using Nerlove-based techniques is likely to be even lower, due to the lengthy planning horizon involved in production of these crops.

An alternative approach is to estimate aggregate response directly using data on aggregate agricultural output, or other broad aggregates like exports or food production. Bond (1983) estimated the effect of prices only on per capita agricultural output in nine SSA countries, correcting for first-order autocorrelation in the error terms. His estimates of short-run supply elasticity (with respect to own price) were generally positive and less than 0.5, although they were statistically insignificant for seven of the nine countries. The interpretation of Bond's results is complicated because all variables were measured in per capita terms. While per capita output is the relevant variable for determining the level of well-being in the society and food security, it is not the appropriate variable for measuring supply response, *per se*. In addition, changes in population are related to changes in agricultural output, so that the left-hand side variables are really a combination of endogenous variables. Moreover, one would like to separate demographic problems, particularly high population growth rates, from problems related to economic incentives.

Balassa (1990) considered the impact of export policies on the agricultural sector in SSA. He used two definitions of export performance, the ratio of (gross) agricultural exports to total agricultural output, expressed as percentage rates of change, and the same ratio adjusted for agricultural imports to give net agricultural exports. He used a pooled regression model

and data on 16 SSA countries. Balassa found that in most cases the exchange-rate coefficient had the expected sign and the elasticity was around 1. The choice of dependent variable in the regression was not ideal and the omission of fixed effects variables may have biased the results and it is impossible to interpret these coefficients as elasticities of supply response.

Jaeger (1992) considered the response of agricultural exports and food imports separately to changing exchange rates and prices. Using a pooled model and correcting for serial correlation and heteroskedasticity in the regression equations, he found that agricultural exports did in fact responded positively to their own price and positively to depreciation of the domestic currency; food imports responded negatively to increases in the price of imported food, measured as a weighted average of the international price of rice and wheat. Jaeger's measure of weather creates some problems. He measured the effect of weather by estimated residuals from a regression of cereal yields on a time trend. To the extent that variables such as price and exchange rates affect cereal yields, these residuals will be correlated with the error term in the supply equation and coefficient estimates will be biased.

3. Exchange rate movements and agricultural production

For countries with a limited manufacturing base, agricultural exports are needed to earn foreign exchange with which to purchase consumer goods and production inputs needed in processing domestic goods. The competitiveness of a country's exports depends on its exchange rate, or, to make the argument differently, the return to domestic producers is an inverse function of the exchange rate. Exchange rate misalignment is thus of serious concern. Indeed, a primary focus of structural adjustment has been correcting the serious exchange rate misalignment in many African countries. An overvalued domestic currency makes imports cheap, providing the upper classes in developing countries with easy access to the foreign consumer goods they demand, and thus is politically attractive, especially for governments which may be weak or unstable. However, an overvalued currency makes a country's exports more expensive on the world market, or alternatively, reduces the

amount which may be paid to domestic producers of exports in terms of the local currency. In addition, imported food becomes cheaper, causing consumers to move down the demand curve and leading to large increases in imported food. Indeed, it is well known that food imports to Africa increased significantly during the late 1970s, a period in which many African currencies became dramatically overvalued (Mellor and Delgado, 1987; Jaeger, 1992).

Consider briefly the effect of exchange rates on relative prices. In most countries in Sub-Saharan Africa, farmers sell their major export crops to government-run marketing boards, which in turn sell them in international markets at the world price. The maximum price the marketing board could pay the farmer (P_d) — ignoring explicit taxes on agriculture, which are not uncommon — is determined by the world price (P_w) and the country's exchange-rate (ER), e.g. $P_d = P_w/ER$. An over-valued currency drives a wedge between the price which the marketing board pays the farmer (in domestic currency) and the price for which it is able to sell the crop on the international market by raising the denominator above (ER), and thus lowering the domestic price of the good. This wedge can be thought of as an implicit tax on agriculture. By depreciating the currency (i.e. lowering exchange rates), the government raises the price it is able to pay farmers for their crops, which should result in increased production.⁵ Moreover, a number of countries place an explicit tax on agricultural goods. This subject has been treated exhaustively by Jaeger (1992), who finds tax rates as high as 85% in some cases. To the extent that adjustment programs which focus on currency depreciation allow agricultural prices to rise, they should result in significant increases in the level of agricultural exports.

4. Price and exchange rate effects on aggregate agricultural output

I begin by estimating the response of aggregate agricultural output to exchange rate and price movements. The impact of changes in food and export crop prices on agricultural output depends on two factors.

⁵ This assumes that the country's exports are a negligible share of the international market, the so-called 'small country' assumption.

The greater the degree of substitutability between export and food crops in production the less impact a change in one price is likely to have on aggregate output. Likewise, the larger the share of total production accounted for by either category, the more important a movement in its price will be for aggregate production. The role of exchange rate movements is also an empirical question. If exchange rate movements are passed through to producer prices, the exchange rate may still help explain aggregate agricultural output if it serves as a proxy for macroeconomic adjustments which affect producer incentives.

Consider the following equation to be estimated:

$$Y_{it} = b_0 + b_1 ER_{it} + b_2 ER_{it-1} + b_3 P_{it}^F + b_4 P_{it-1}^F + b_5 P_{it-1}^e + b_6 P_{it}^e + b_7 RN_{it} + b_8 RN_{it}^2 + u_{it} \quad (1)$$

where Y_{it} is a measure of aggregate agricultural output for country i in year t . In this case, aggregate output is measured using the Food and Agriculture Organization's (FAO) index of total agricultural production denominated in local currency, available in the FAO Production Yearbook.⁶ ER is the IMF's real effective exchange rate, e.g. the trade-weighted exchange rate between the country and its major trading partners, adjusted for the relative rates of inflation in each country, again measured for country i in year t .⁷ Prices for domestic food crops and export crops are given by P^F and P^e respectively, for country i and year t as well. Price indices were created for food and export crops in each country, using data on crop prices for each country's major export and food crops, recently made available by the World Bank in the African Development Indicators.⁸ Indices of producer prices were created using the Laspeyres formula and then deflated by the IMF's Consumer Price Index (CPI) series to achieve a measure of real prices. RN is a measure of rainfall in each country's primary

⁶ FAO index numbers are created using a Laspeyres formula. See the FAO Production Yearbook for more details (FAO, various years).

⁷ This is available from the IMF's *International Financial Statistics* for years following 1979. I thank the IMF for making available the data before 1979.

⁸ I am grateful to Marcello Baptista of the World Bank for assistance in interpreting and utilizing the data in ADI (World Bank, 1992).

agricultural growing region during the main growing months of the crop year.

Since data from a set of countries across 16 years was used, some care must be taken in modeling the error term u_{it} in Eq. (1). A number of possible options are available. If the set of observations for a given country are thought to contain country-specific unobservable factors which might be correlated with the variables used in the regression, then the appropriate statistical technique is to allow the intercept term to vary across countries, giving rise to the ‘fixed-effects’ estimator. If the country-specific effects are taken as parameters to be estimated, then they are subsumed in the variance of the error term, giving rise to the ‘random effects’ estimator. The advantage of the fixed effects estimator is that it corrects for the presence of country-specific fixed effects which would otherwise bias the results in the same way as omitted variables (Judge, 1985, pp. 519–521). On the other hand, estimates are inefficient relative to random effects if random effects are the appropriate model.

In principal, one could test for the presence of fixed versus random effects, using a Hausman-type test (Hausman, 1978). However, it is well known that these tests are characterized by low power, especially in small samples (Nakamura and Nakamura, 1985) so I impose fixed effects. The parameter b_0 is allowed to vary across countries, e.g. b_0 becomes b_{0i} . This is achieved by including a set of dummy variables, which take on the value 1 for observations on a given country and zero elsewhere. To determine whether the fixed effects added to the regression, F -tests were performed for the joint significance of the set of dummy variables in the regressions; in all cases the null hypothesis that the dummy variables were jointly equal to zero was rejected. This suggests that fixed effects are likely the appropriate statistical model for the data at hand.

Two other econometric complications arise in estimating Eq. (1). First, the price of domestically produced food may well be endogenous to the regression being estimated, since the price of domestic food is determined by demand for and supply of food available in the local market. Therefore instrumental variables (two-stage least squares) estimation is used to correct for the possible endogeneity of the food price variable, where the set of instruments for food price

included variables likely to affect the *demand* for food and likely to be correlated with food prices: lagged values of food and export prices and the exchange rate, income, net transfers and the price of imported food.⁹ Secondly, the variance term u_{it} may well be heteroskedastic, e.g. $E\{u_{it}\} = \sigma_i^2$. To control for heteroskedasticity, I use weighted two-stage least squares where the weights were inversely proportional to the square of the dependent variable, a common correction for heteroskedasticity.¹⁰

Eq. (1) is a simple direct test of the proposition that food crops and export crops are substitutes in production. In particular, if food and export crops compete for limited inputs in African agriculture, then the coefficient on either price may be statistically insignificant (not statistically different from zero), since an increase in one price would lead to a shift of resources away from production of food crops to export crops, or vice versa. The sign on the exchange rate is ambiguous. In particular, if exchange rate liberalization is accompanied by changes in the macroeconomic environment (which are not measured directly here) then including the exchange rate directly in the equation will pick up the effects of those changes. And if movements in the exchange rate are not fully passed through to prices at the farmgate, then including the exchange rate in the regression may measure the importance of the implicit tax on agricultural production represented by overvalued currencies.

Empirical estimates for the total agricultural output regression are reported in Table 2, for a number of different econometric specifications. By visual inspection of the data at hand, Nigerian data for 1987–1990 appear to be statistical outliers (see Appendices A and B).¹¹ Including these data in the regression might lead to biased results, so I excluded Nigeria from the sample for years 1987–1990. I first estimated the full model specified in (1), including both contemporaneous and lagged prices on the right-hand side; results

⁹ This set of instruments was influenced by the structural model considered below.

¹⁰ Although I did not include the results without weighting, the parameter estimates were quite similar to those using weighted 2sls.

¹¹ Nigeria presents special problems for a number of reasons. It is widely accepted that much of the basic data for Nigeria is unreliable. Nigeria had significant oil earnings over the period considered here.

Table 2

Aggregate agricultural supply functions^{a,b}

	(1) IV	(2) IV	(3) LS	(4) IV	(5) LS
Dependent variable: natural logarithm of agricultural output					
Log of domestic food price	−0.50 (−0.92)	0.14 (1.72)*	***	0.16 (1.43)	***
Log of export price	−0.02 (−0.08)	−0.31 (5.13)***	***	−0.32 (−4.14)***	***
Log of the real exchange rate	−0.29 (−3.23)***	−0.17 (−3.94)***	***	−0.18 (−3.88)***	***
Rainfall during growing season	0.65 (1.38)	0.53 (1.37)	0.43 (1.06)	0.24 (0.36)	0.24 (0.33)
Rainfall during growing season, squared	−0.04 (−1.36)	−0.03 (−1.31)	−0.03 (−1.00)	−0.02 (−0.34)	−0.01 (−0.30)
Log of domestic food price, lagged	0.42 (1.21)	***	0.09 (1.53)	***	0.06 (0.83)
Log of export price, lagged	−0.22 (−1.49)	***	−0.25 (−4.52)***	***	−0.21 (−3.49)***
Log of the real exchange rate, lagged	0.18 (1.63)	***	−0.12 (−2.53)**	***	−0.17 (−3.20)***
<i>F</i> -test for fixed-effect dummy variables (<i>p</i> -value)	5.51 (0.00)	7.99 (0.00)	6.67 (0.00)	6.90 (0.00)	6.05 (0.00)
<i>F</i> -test for period <i>t</i> prices & exchange rates	5.52 (0.00)	13.75 (0.00)	***	12.79 (0.00)	***
<i>F</i> -test for period <i>t</i> −1 prices	1.51 (0.21)	***	7.70 (0.00)	***	6.57 (0.00)
<i>F</i> -test for joint significance of export prices	6.82 (0.00)	***	***	***	***
<i>F</i> -test for joint significance of food prices,	1.82 (0.17)	***	***	***	***
<i>F</i> -test for joint significance of exchange rates	3.59 (0.06)	***	***	***	***
Hausman (χ^2) test for endogeneity of the food price (<i>p</i> -value)	***	38.27 (0.00)	***	33.91 (0.01)	***

^a *t*-Statistics are reported in parentheses.^b Observations are weighted to reflect heteroskedasticity across observations in the data.

* Statistically significant at the 10% level.

** Statistically significant at the 5% level.

*** Statistically significant at the 1% level.

are reported in column (1). The overall fit of the regression is strong (the *F*-test for the model is significant at the 1% level), but the effect of individual variables are not well identified, suggesting a high degree of multicollinearity among regressors. Nonetheless, most parameter estimates fell within reasonable ranges, and suggests relatively modest short-run supply response to prices and exchange rates. Period *t* prices and the exchange rate are jointly statistically significant at the 1% level, but period *t*−1 prices are significant only at the 20% level. Given the likely collinearity of the two variables, this is perhaps not surprising. Dummy variables for the fixed effects are jointly significant at

the 1% level as well. Current and lagged export prices are jointly significant at the 1% level, and the sum of the coefficients is about −0.24.¹² Coefficients on the current and lagged exchange rate are jointly significant at the 6% level, and the sum of the coefficients is −0.11.

Since the full model is unable to identify parameter estimates with a high degree of precision, I considered two special cases of the model. I find fairly convincing evidence that aggregate agricultural output responds

¹² Since these regressions are in log–log form, coefficients may be interpreted as elasticities.

positively to food prices with an elasticity between 0.1 and 0.15, and negatively to export prices, with an elasticity close to -0.3 . The exchange rate is negatively correlated with aggregate output even when conditioning on prices. The fixed-effects model appears to be appropriate for these data.

First, I restricted the coefficients on lagged prices and the exchange rate to be zero; I assume that only current period prices affect output. I continued to treat current-period food prices as endogenous, so two-stage least squares regression is used. Results are shown in column (2) of Table 2. The elasticity of total agricultural production with respect to food prices is estimated to be 0.14, and the elasticity with respect to export prices is estimated to be -0.31 ; the coefficient on export prices is statistically significant at the 1% level. The elasticity of total output with respect to the exchange rate is -0.17 . In this simpler model, I found that fixed-effects dummies are jointly statistically significant at the 1% level. I also perform a Hausman test for the endogeneity of the food price (Greene, 1997, pp. 761ff). I am able to reject a null hypothesis that current-period food price is exogenous at the 1% level.

Since estimates based on two-stage least squares are subject to greater uncertainty (the use of instrumental variables results in parameter estimates with higher standard errors), I also estimated an alternative model in which aggregate supply responds to lagged prices and the lagged value of the exchange rate. This model — which certainly goes back as far as Nerlove's (1958) pioneering work — assumes that farmers form expectations of price for year t based on price the previous year, $t-1$. The results of this analysis (column (3)) are quite similar to those in which I conditioned on current-period prices, suggesting that the model is fairly stable. The price and exchange rate variables are jointly significant at the 1% level. I find that the elasticity of total agricultural output with respect to food price drops slightly, to 0.09, and the response to export prices also drops (in absolute value) to -0.25 , but is still statistically significant at the 1% level. The elasticity with respect to the real exchange rate is -0.12 and statistically significant at the 5% level.

One concern with the statistical results discussed here is that they may be sensitive to the sample used in estimation, e.g. one or two statistical outliers could

generate the results. I used a statistical procedure programmed in Stata to identify multivariate statistical outliers.¹³ The statistical analysis identified 22 observations which were outliers; these observations were excluded from the sample and the equations estimated on the smaller sample. Results from this sub-sample of the data are reported in columns (4) and (5). The results based on the smaller sample do not differ qualitatively from those based on the full sample, for either the specification based on current-period prices (column(4)) or lagged period prices (column(5)). The lagged value of food prices does have a weaker statistical relationship with aggregate agricultural output, although it is still positive. Prices are jointly statistically significant as before. This suggests that the statistical relationship is fairly robust in this data.

For the African countries considered here, aggregate agricultural output increases with increases in food prices, but declines with increases in the export price and the exchange rate. The perverse relationship between export price and total agricultural output is consistent with the view that export crop production is only mildly affected by current period prices. In particular, most export crops in the African context take several years to reach maturity, so increases in price today can do little to raise today's production. However, as resources are shifted into producing larger crops for future export, food production today certainly may decline, and this is a plausible explanation for the negative correlation between export price and aggregate output.

The negative relationship between the exchange rate and agricultural output, which is persistent, robust, and statistically significant, could reflect a number of possible explanations. Exchange rates impact on crop production decisions in a number of ways. Because an overvalued currency makes imported food cheaper, a currency devaluation will raise the price of imported food and shift demand for locally produced food up, raising domestic food prices and domestic production. In this case, the exchange rate may be negatively associated with export production even if the changes in the exchange rate are fully passed into domestic prices. An overvalued exchange rate lowers the price

¹³ The statistical routine is Stata's *hadimvo* routine for identifying multivariate outliers. For further details, refer to the Stata Reference Manual Release 6.0, Volume 2.

in terms of domestic currency which government marketing boards are able to pay for export crops, *ceteris paribus*. So the exchange rate is negatively correlated with export production. Changes in the exchange rate may not be passed through to export prices immediately, so that the exchange rate variable is picking up the effect of the implicit tax on agriculture. Alternatively, it may be that the exchange rate variable acts as a proxy for other macroeconomic forces not modeled here but which may accompany a program of structural adjustment, such as government fiscal restraint or the level of overall taxation.

5. A structural model of agricultural demand and supply

The results above suggest that more information is needed on the degree to which food crops and export crops may be substitutes in production and the magnitude of the response to price. Export crops might be favored over food crops as declining exchange rates allow the government to increase the price paid to farmers for export crops, shifting the internal terms of trade in their favor. Moreover, in those cases where the country holds a significant market share, the country may be able to lower the external price for the good, driving up demand. In contrast, a depreciation in the country's terms of trade would raise the price of imported food and could thus shift demand for locally produced food. A more structural approach to estimating the impact of prices and exchange rates on the food and export crop supply is warranted.

I consider a structural model of the demand for and supply of food and export crops. I consider the case of a farmer who chooses between production of export crops and (domestic) food crops and a consumer who purchases both imported and domestic food. Such a production environment gives rise to a system of demand and supply equations to be estimated:

$$\begin{aligned} \ln Q_{S,t}^F = & a_{10} + a_{11} \ln P_t^F + a_{12} \ln P_{t-1}^F \\ & + a_{13} \ln P_t^E + a_{14} \ln P_{t-1}^E \\ & + a_{15} \ln RN_t + a_{16} \ln RN_t^2 + u_{1t} \end{aligned} \quad (2)$$

$$\begin{aligned} \ln Q_{D,t}^F = & a_{20} + a_{21} \ln P_t^F + a_{22} \ln P_t^I \\ & + a_{23} \ln INC_t + a_{24} \ln ER_t + u_{2t} \end{aligned} \quad (3)$$

$$\begin{aligned} \ln Q_{D,t}^I = & a_{30} + a_{31} \ln P_t^F + a_{32} \ln P_t^I \\ & + a_{33} \ln ER_t + a_{34} \ln INC_t \\ & + a_{35} \ln TRANS_t + u_{3t} \end{aligned} \quad (4)$$

$$\begin{aligned} \ln Q_{S,t}^E = & a_{40} + a_{41} \ln P_t^F + a_{42} \ln P_{t-1}^F \\ & + a_{43} \ln P_t^E + a_{44} \ln P_{t-1}^E \\ & + a_{45} \ln ER_t + a_{46} \ln ER_{t-1} + a_{46} \ln RN_t \\ & + a_{47} \ln RN_t^2 + u_{4t} \end{aligned} \quad (5)$$

where superscripts I, F and E denote imported food, domestic food production, and export crop production, respectively. Subscripts D and S denote demand and supply, respectively. TRANS is defined to be the total net transfers to the country from abroad, including IMF credits. INC is real income, ER is the real effective exchange rate index (as defined above), and RN is rainfall (measured as above).

The model assumes that domestic and imported foods are substitutes in consumption. Eq. (3) gives the demand for domestic foods (Q_D^F), which is assumed to be a log-linear function of the price of domestic food (P_t^F), the price of imported foods (P_t^I), per capita income, and the exchange rate. Demand for domestic food is expected to respond positively to the price of imported food, since they are substitutes in consumption. Higher income raises the demand for food. If changes in the exchange rate are fully passed to consumer prices, then the ER may still be significantly related to food demand if it proxies for other changes in the country's macroeconomic regime, but the sign of the relationship would be ambiguous. Demand for imported food (Q_D^I), Eq. (4), is a log-linear function of domestic and imported food prices, the exchange rate and income, as well as the level of net transfers. Food demand is usually thought to be highly income elastic in developing countries. Demand for imported foods is assumed to be a function of the level of net transfers, reflecting the possibility that demand for food imports may be constrained by a lack of effective purchasing power if the country has little or no foreign exchange earnings; Transfers provide a means of loosening the constraint.

More interesting for the purposes of this paper are the supply equations for domestic food and exports embodied in Eqs. (2) and (5). Supply of domestic food crops (Q_S^F), Eq. (2), is assumed to depend on

the real producer prices of food and export crops (P^F and P^E , respectively), the level of rainfall, and rainfall squared. As in Eq. (1) above, both the current period and lagged values of prices are allowed to influence the supply of domestic food. The lagged value of food prices may play an important role in helping producers forecast food prices at planting time, when the actual price may be unknown. Including lagged values of prices allows for great flexibility in the empirical relationship. The supply of export crops (Q_S^E), Eq. (5) is a function of the real producer prices of export and food crops, the exchange rate, and rainfall and rainfall squared. This is a minimalist approach to estimating the supply framework, involving a fairly sparse econometric specification. Food crops and export crops are assumed to be substitutes in production, so prices of both are included. Rainfall is measured in each country's primary agricultural region over the main growing months. I assume that the supply of imported food, and the demand for the country's agricultural exports are perfectly elastic at the world price, consistent with the 'small country' assumption, and are thus exogenous.¹⁴

I am primarily interested in estimating the structural parameters of the food and export supply functions, Eqs. (2) and (5), respectively. This allows me to recover the short-run supply response to prices and the exchange rates. The price of food crops is endogenous to the demand and supply system considered here, so using ordinary least-squares applied to (2) and (5) would lead to simultaneous equation bias. I use a two-stage least squares procedure to estimate the structural parameters of the export and food supply equations. The basic condition for identification is that there are enough excluded exogenous variables to serve as instruments for the endogenous right-hand side variables in (2) and (5). In this case the price of imported food, total net transfers, and income are all possible instruments, so that the parameters of Eqs. (2)–(5) are in fact identified. I first regress the endogenous price variable, P^F , on those exogenous variables appearing in the remainder of the system: P^E , ER, RN, RN^2 , TRANS, INC, and P^I and the fixed effects dummies. The fitted values of food price from

the first-stage regression are uncorrelated with the error terms in Eqs. (2) and (5), so that estimates obtained from the second stage regression are free from simultaneity bias.

In principle, there are also a number of cross-equation restrictions on output response to own-price and cross-price changes suggested by economic theory. Imposing these restrictions yields more efficient estimates if the equations are correctly specified. There are, however, caveats: incorrect specification of the equations or error terms will result in greater errors if cross-equation restrictions are imposed. I choose to ignore cross-equation restrictions in this paper. Moreover, using two-stage least-squares assumes that the structural error terms u_1 – u_4 are independent across equations. While this is something of a strong assumption, modeling the error structure more fully is an exercise that may add little to the econometric estimates, especially given the small sample involved here.

I assume that fixed-effects is the appropriate statistical model, an assumption which seems to be supported by the results of F -tests reported below. I also assume that the data are described by country specific heteroskedasticity, e.g. $E\{u_{it}\} = \sigma_i^2$.

5.1. Food supply

The structural parameter estimates for the food supply equation, Eq. (2), are given in Table 3. I find fairly convincing evidence that food crops and export crops are substitutes in production in the short run, although the elasticities are fairly small. Food production is negatively related to export prices and positively related to its own price.

I first estimated the full model on a sample of data that excluded Nigeria for the years 1987–1990, due to the likely presence of statistical outliers (see Appendix B); results are shown in column (1) of Table 3. I controlled for both current-period and lagged prices. While the overall fit of the model to the data is good (the F -test for the overall model is significant at the 1% level), the model is not able to separately identify the coefficients on individual variables very effectively, likely reflecting the high degree of multicollinearity in the regressors. Of the individual price variables, only the lagged value of export price is close

¹⁴ This is clearly violated in the case of some African countries, for example Ghanaian cocoa. To model market power assumptions more carefully is beyond the scope of this paper.

Table 3
Food supply functions^{a,b}

	(1) IV	(2) IV	(3) LS	(4) IV	(5) LS
Dependent variable: natural logarithm of food supply					
Log of domestic food price	−0.40 (−0.84)	0.17 (1.82)*	***	0.25 (2.04)**	***
Log of export price	−0.03 (−0.17)	−0.30 (−4.72)***	***	−0.36 (−4.28)***	***
Rainfall during growing season	0.74 (1.60)	0.65 (1.59)	0.52 (1.27)	0.49 (0.67)	0.42 (0.56)
Rainfall during growing season, squared	−0.05 (−1.50)	−0.04 (−1.45)	−0.03 (−1.14)	−0.03 (−0.59)	−0.02 (−0.49)
Log of domestic food price, lagged	0.37 (1.22)	***	0.11 (1.53)	***	0.11 (1.45)
Log of export price, lagged	−0.22 (−1.55)	***	−0.24 (−4.27)***	***	−0.21 (−3.20)***
F-test for fixed-effect dummy variables (p-value)	6.28 (0.00)	7.92 (0.00)	6.90 (0.00)	5.53 (0.00)	5.36 (0.00)
F-test for period <i>t</i> prices	3.81 (0.02)	12.55 (0.00)	*** **	11.10 (0.00)	***
F-test for period <i>t</i> −1 prices	1.23 (0.30)	***	9.18 (0.00)	***	5.29 (0.00)
F-test for joint significance of export prices	7.85 (0.00)	***	***	***	***
F-test for joint significance of food prices	2.20 (0.11)	***	***	***	***
Hausman (χ^2) test for endogeneity of the food price (p-value)	***	33.97 (0.00)	***	33.58 (0.01)	***

^a *t*-Statistics are reported in parentheses.

^b Observations are weighted to reflect heteroskedasticity across observations in the data.

* Statistically significant at the 10% level.

** Statistically significant at the 5% level.

*** Statistically significant at the 1% level.

to statistically significant at the 10% level. *F*-tests for joint significance of the fixed-effect dummy variables reject a null hypothesis that they are jointly equal to zero, suggesting that fixed effects are the appropriate model. Current period prices are jointly statistically significant at the 2% level, while lagged prices are not significantly different from zero (as in Table 2 specifications above). The current and lagged food prices are jointly significant at the 11% level, while current and lagged export prices are significant at the 1% level.

To identify better the effects of food and export prices on food supply, I also estimated the model with the same sample but conditional on current period prices only, e.g. restricting the effect of lagged prices to be zero. These results (column (2)) suggest that food supply responds positively to its own price

and negatively to the contemporaneous export price. The estimated supply elasticity for food crops with respect to their own price is 0.17, somewhat higher than might have been expected, and the coefficient is statistically significant at the 10% level. Export prices have a negative effect on food production, and the estimated elasticity is about −0.30; the coefficient is statistically significant at the 1% level. The fixed effects dummy variables are jointly statistically significant at the 1% level, as are food and export prices. A null hypothesis that food price is exogenous is rejected at the 1% level using a Hausman chi-squared test.

I also estimated the food supply model conditional on lagged prices only (column (3) of Table 3). If farmer's use lagged prices to form expectations of current year's price at planting time, then this is the ap-

propriate statistical model. The estimation results are little different in this case, although the own-price effect of food price on food supply is somewhat attenuated. Food supply responds negatively to export prices, with an estimated elasticity of -0.24 (significant at the 1% level), roughly the same as the specification conditional on current period prices. I continue to find that the fixed-effects dummy variables are statistically significant.

To deal with the concern that these results are sensitive to the presence of statistical outliers, I used a statistical procedure programmed in Stata to identify multivariate statistical outliers. The statistical analysis identified 22 observations which are outliers; these observations are excluded from the sample and the equations estimated on the smaller sample. The results based on the smaller sample — shown in columns (4) and (5) of Table 3 — do not differ qualitatively from those based on the full sample, for either the specification based on current-period prices (column(4)) or lagged prices (column(5)). Interestingly, the food price coefficient is significant at the 5% level in these estimates, suggesting a higher level of confidence in the variable's significance. This suggests that the statistical relationship is fairly robust in this data.

The fairly convincing statistical evidence that food crops respond negatively to the contemporaneous export price (albeit with a fairly moderate elasticity) confirms the 'eyeball' regression from the graphs in Appendix B. Nonetheless, the fact that current period export prices can affect food production, e.g. that food crops and export crops are substitutes in production, may strike some as odd. Export crops in Africa may take several years to reach maturity (tobacco and cotton being notable exceptions) and do not necessarily compete with food crops for land. However, export crops may well compete with food crops for other scarce inputs, for example labor resources. A rise in the price of export crop may lead producers to shift labor (and other inputs) away from food crop production, as these results suggest. Moreover, there may not be an accompanying rise in export production *in that year*, since it takes several years for export crops to reach maturity. Hence aggregate agricultural output falls with increases in the export price at least in the short run, consistent with the results in Table 2 above.

5.2. *Export supply*

Finally, I consider the response of agricultural exports to food and export prices and the exchange rates. The empirical estimates of the food supply equation suggest that food prices should be negatively related to export supply. Export prices should be positively correlated with export supply, although as argued above the relationship may be weak given the significant lags involved in producing many export crops in Africa. The role of exchange rates is somewhat ambiguous, although earlier empirical results (Section 4 above) suggest that exports are likely to be negatively correlated with export supply.

I estimated the response of agricultural exports to current and lagged food prices, export prices, and the exchange rate using the same set of indices as above, controlling for rainfall effects, using fixed-effects dummy variables and allowing for heteroskedasticity across countries in the error term. I used the FAO's index of non-food production as a measure of export supply; while this measure falls short of an exact measure of export production it does a reasonably good job of identifying production of crops intended for export. The results of these regressions are reported in Table 4, for the same set of subsamples and the same model specifications as in the case of food supply above. As before, the general model specification (column (1)) performs rather poorly in identifying the structural parameters, likely reflecting multicollinearity among regressors. Therefore I proceed to the consideration of two simpler models based on current and lagged values, considered separately, of prices and the exchange rate.

For the simpler model in which only current prices enter the export supply equation (column (2)), the regression did a good job of identifying the effect of individual variables. The export price was only statistically significant at the 15% level, although the estimated elasticity, 0.25, was reasonable. Given the lags in production of some export crops, the weak statistical relationship is perhaps not surprising. Food prices and exchange rates are statistically significant at the 1% and 5% level, respectively. The elasticity of exports with respect to a change in food prices was found to be -0.82 , suggesting a substantial degree of substitutability. The fairly large elasticity may well reflect a greater importance of food crops than export crops

Table 4
Export supply functions

	(1) IV	(2) IV	(3) LS	(4) IV	(5) LS
Dependent variable: natural logarithm of non-food agricultural production ^a					
Log of domestic food price	−0.22 (−0.14)	−0.82 (−3.29)***	***	−0.74 (−2.31)**	***
Log of export price	0.04 (0.07)	0.25 (1.46)	***	0.15 (0.71)	***
Log of the real exchange rate	−0.37 (−1.67)*	−0.30 (−2.41)**	***	−0.30 (−2.24)**	***
Rainfall during growing season	−0.31 (−0.28)	−0.23 (−0.21)	−0.29 (−0.27)	−1.38 (−0.69)	−1.24 (−0.62)
Rainfall during growing season, squared	0.01 (0.17)	0.00 (0.09)	0.01 (0.18)	0.08 (0.59)	0.07 (0.54)
Log of domestic food price, lagged	−0.39 (−0.40)	***	−0.54 (−3.41)***	***	−0.57 (−2.85)***
Log of export price, lagged	0.15 (0.37)	***	0.16 (1.03)	***	0.11 (0.60)
Log of the real exchange rate, lagged	0.07 (0.30)	***	−0.26 (−1.92)*	***	−0.27 (−1.85)*
<i>F</i> -test for fixed-effect dummy variables (<i>p</i> -value)	1.62 (0.08)	2.47 (0.00)	2.54 (0.00)	2.00 (0.02)	6.05 (0.00)
<i>F</i> -test for period <i>t</i> prices and exchange rates	0.95 (0.42)	5.90 (0.00)	***	3.82 (0.01)	***
<i>F</i> -test for period <i>t</i> −1 prices and exchange rates	0.14 (0.93)	***	5.06 (0.00)	***	3.78 (0.01)
<i>F</i> -test for joint significance of export prices	0.64 (0.53)	***	***	***	***
Dependent variable: natural logarithm of non-food agricultural output ^b					
<i>F</i> -test for joint significance of food prices	5.56 (0.00)	***	***	***	***
<i>F</i> -test for joint significance of exchange rates	3.12 (0.05)	***	***	***	***
Hausman (χ^2) test for endogeneity the food price (<i>p</i> -value)	***	26.14 (0.09)	***	24.77 (0.13)	***

^a *t*-Statistics are reported in parentheses.

^b Observations are weighted to reflect heteroskedasticity across observations in the data.

* Statistically significant at the 10% level.

** Statistically significant at the 5% level.

*** Statistically significant at the 1% level.

in total agricultural production. The elasticity of exports with respect to the exchange rate is −0.30 and statistically significant at the 5% level, indicating the importance of the exchange rate in explaining agricultural output in these countries. Fixed effects dummies are jointly significant at the 1% level, as are prices and the exchange rate. The Hausman test rejects a null hypothesis that food prices are exogenous at the 10% level.

When I condition the regression only on lagged prices and the lagged exchange rate (column (3)) results are qualitatively similar. The estimated elasticity of export production with respect to food price is

smaller (in absolute value), at −0.54 and significant at the 1% level. This value is perhaps more believable than the larger estimate of −0.82. Fixed effects dummies are jointly significant at the 1% level, as are prices.

To deal with concerns about robustness of the estimation results, I also estimated model parameters on a subsample that excluded multivariate outliers (columns (4) and (5)). The estimates support the view that food crops and export crops are substitutes in the short run. In both models the exchange rate variable and the food-price variable are statistically significant, while export price is not. The estimated elasticities are

similar in magnitude to those obtained from the larger sample. However, the coefficients are estimated with less precision than before, and *t*-statistics are always smaller. This suggests some lack of robustness in the export model.

The estimates of export supply suggest that exports and food crops are substitutes in production, with contemporaneous food prices having a substantial effect on export production. That the export price has only a limited effect on exports in the short run is perhaps not surprising given the nature of export crops in these countries. Estimating a fuller dynamic specification that would identify the lags between price changes and supply response would be a useful exercise, but lies beyond the scope of this paper.

6. Conclusion

I find substantial evidence in this paper that food crops and export crops are substitutes in production in African agriculture. The cross-price elasticities for food and export supply functions are negative and statistically significant, and fall within reasonable ranges when compared with previous estimates. Evidence also suggests that while aggregate agricultural output responds positively to increases in food prices, it responds negatively to increases in export prices, *in the short run*. A possible explanation is that increases in export price lead farmers to shift resources into production of export crops and out of food crops. While the negative impact on aggregate output through lower food production is immediate, the contribution of greater export crop production may take several years to materialize, given the lags in production of many African export crops. The fairly weak relationship between export price and short run supply response for export crops is consistent with this explanation.

I also find a persistent and robust negative relationship between the exchange rate and aggregate agri-

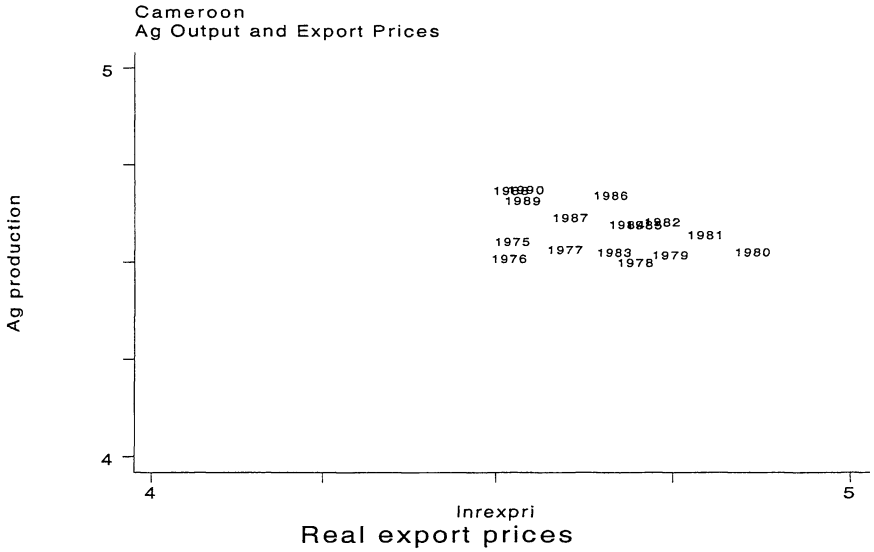
cultural output, even when I condition on both export and food prices. This suggests a number of possible forces at work. The exchange rate may be proxying for other, unobserved macroeconomic variables, and the beneficial effects of adjustment on these variables is leading to a positive effect on agricultural output. Another explanation is that changes in the exchange rate are not fully passed through to prices immediately, so the exchange rate still has a role to play in explaining production.

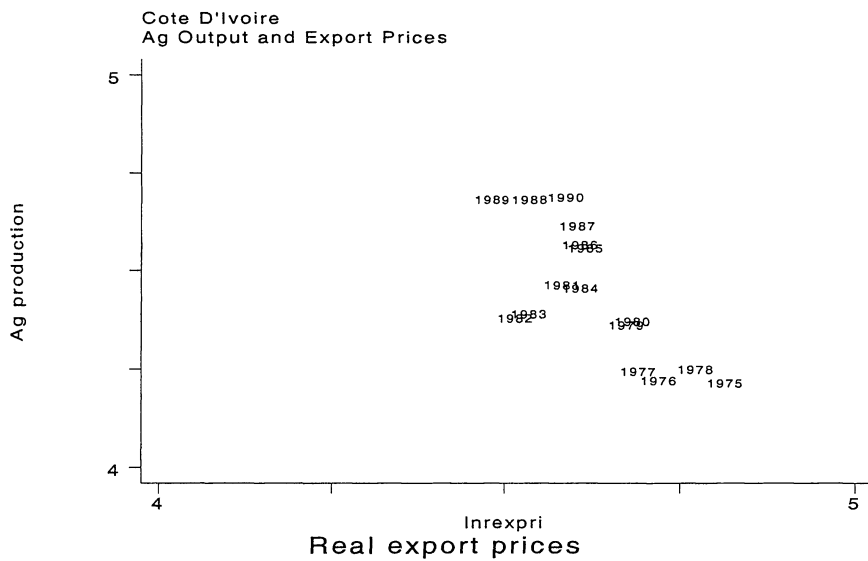
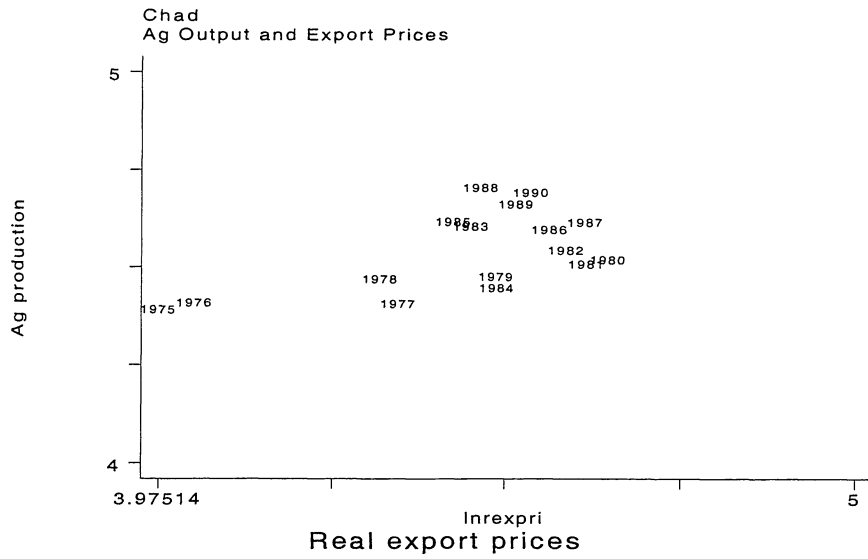
While the impact of adjustment on agriculture has substantial implications for policy, conclusions should be drawn from the present exercise with some caution. The strongest result, that food crops and export crops are substitutes in production in the short run, has little to say about the longer run implications of adjustment for aggregate agricultural output. The greatest concern with this finding is that structural adjustment might result in short run, that is temporary, declines in agricultural output leaving countries vulnerable to declines in domestic food without adequate foreign exchange earnings to purchase food in world markets. Such effects should correct themselves over time as export production responds. That the exchange rate is an important variable affecting aggregate output negatively, even in the short run, highlights the possible beneficial effects of adjustment on aggregate agricultural output, especially in the longer run. Further study is needed, especially at the micro level, to determine with greater precision the effect of price and exchange rate policy on African agriculture, especially in the long run.

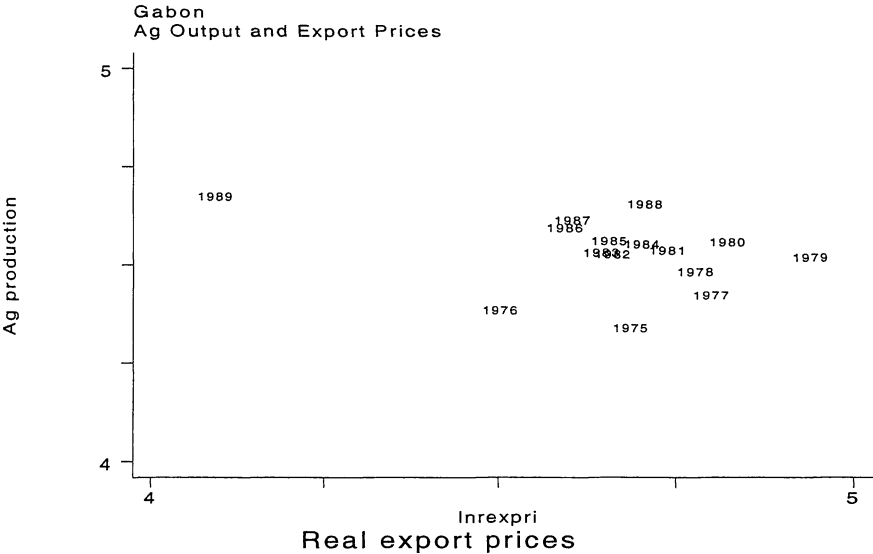
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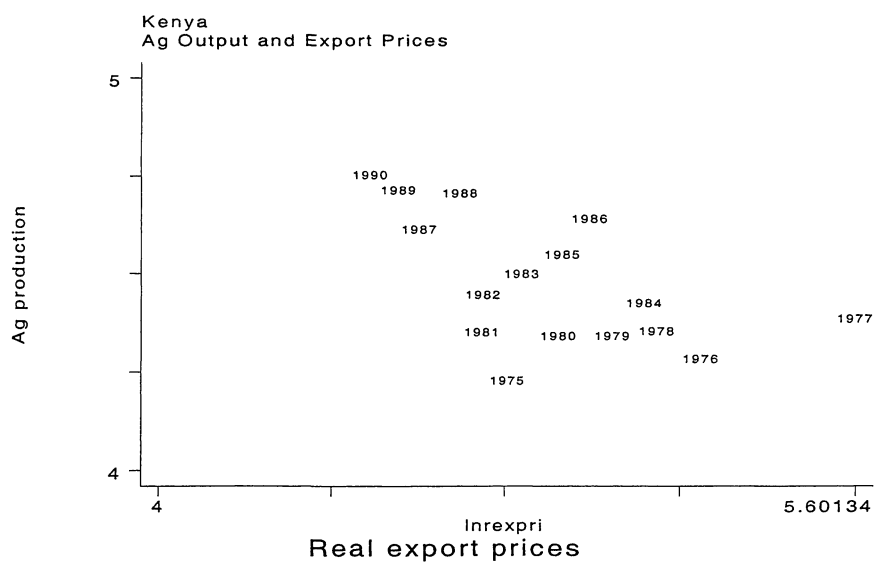
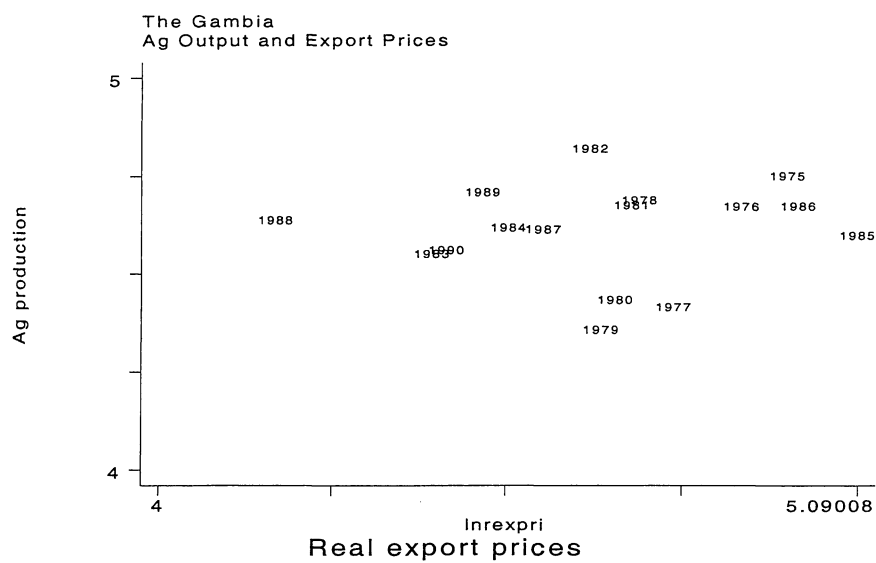
I would like to thank Graeme Donovan, Jere Behrman, Marcello Baptista, Kevin Cleaver, Ibrahim Elbadawi, Graham Farmer and Christine Jones for useful suggestions at various stages of the paper. Svetlana Edmeades provided research assistance. All remaining errors are mine alone.

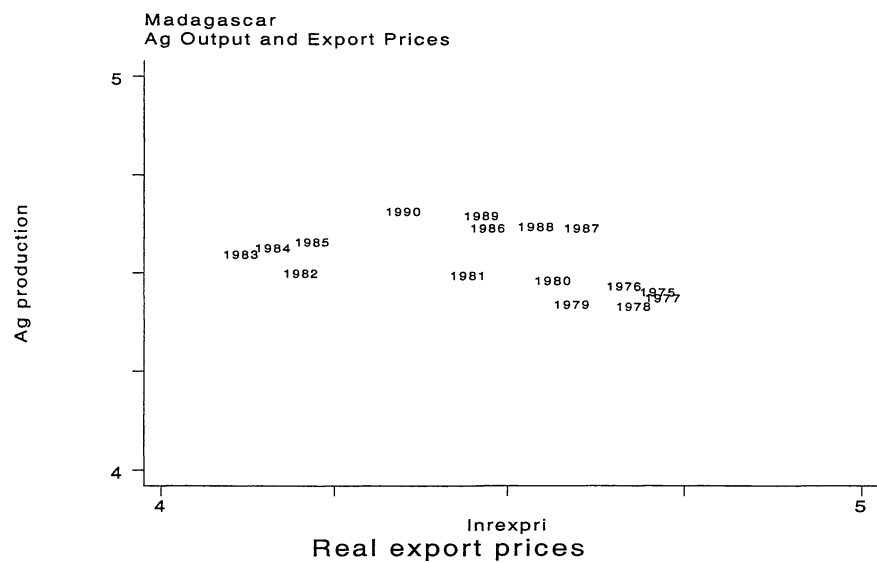
Appendix A. Graphs: agricultural output and export prices, by country

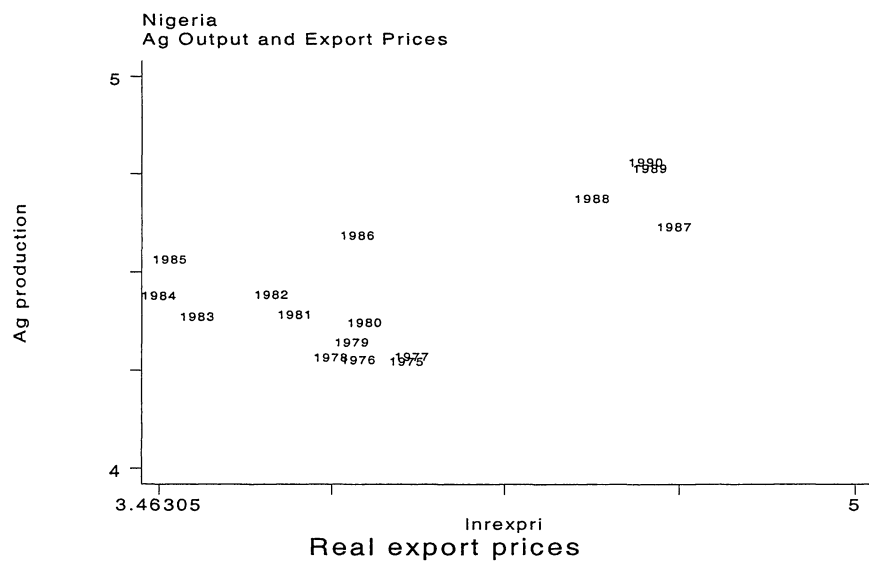
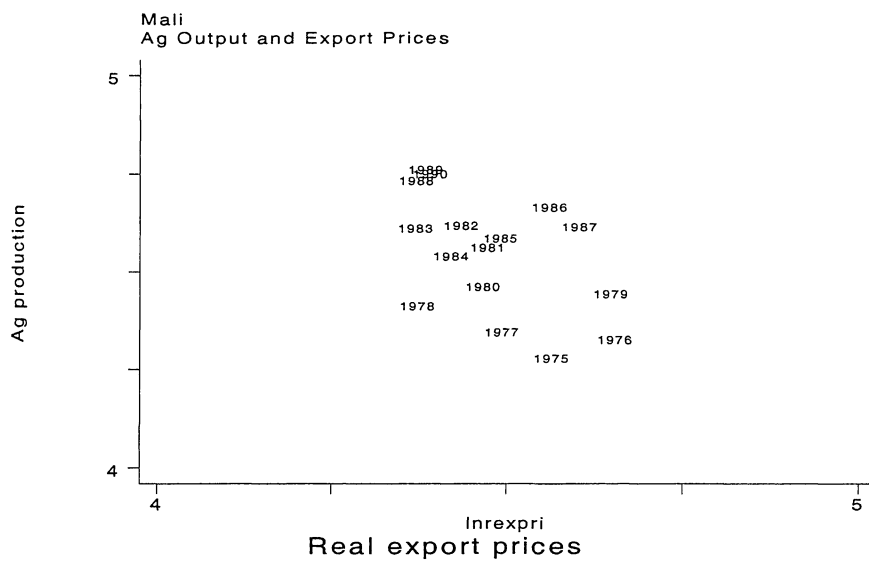


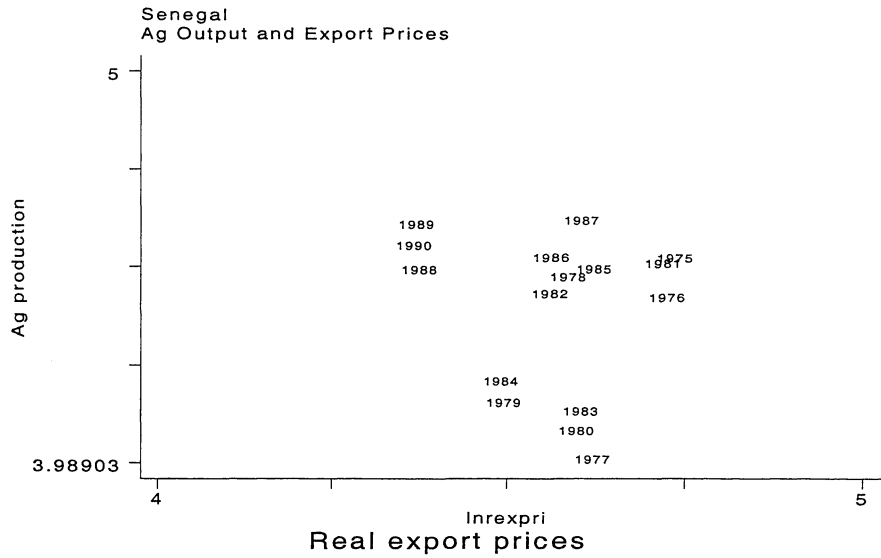


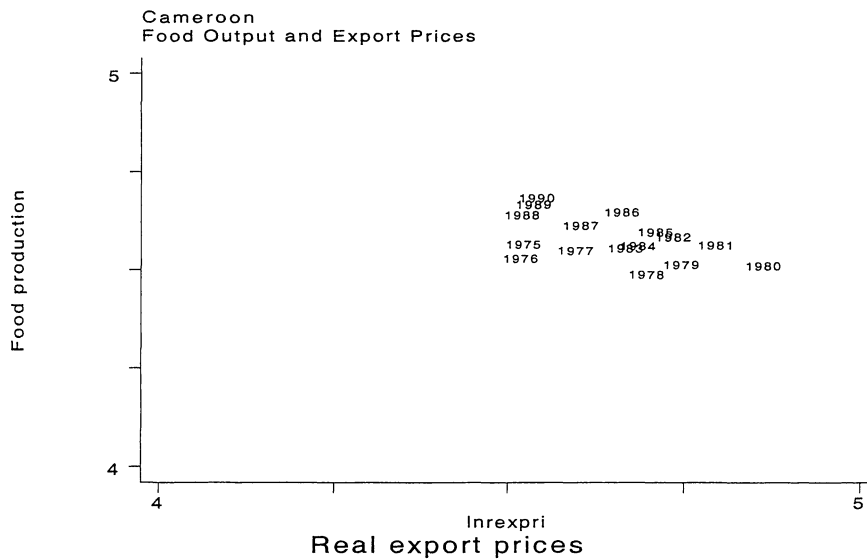
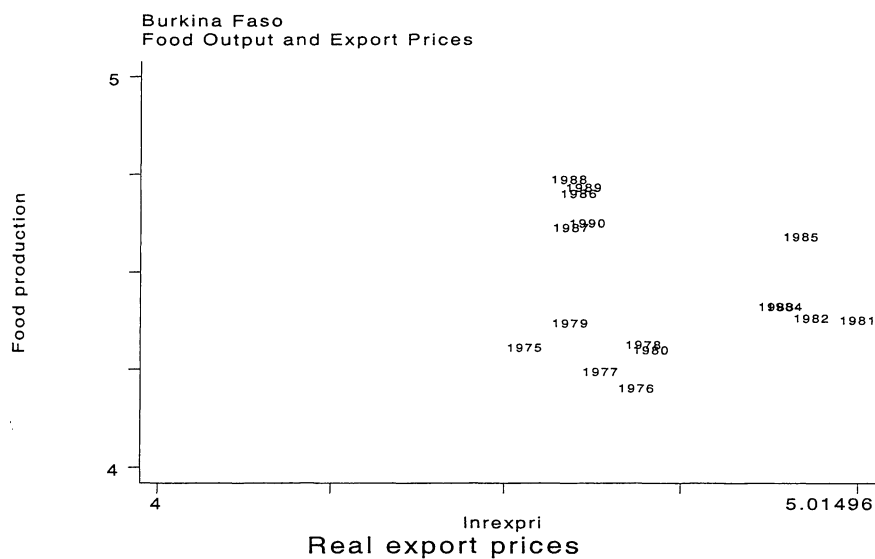


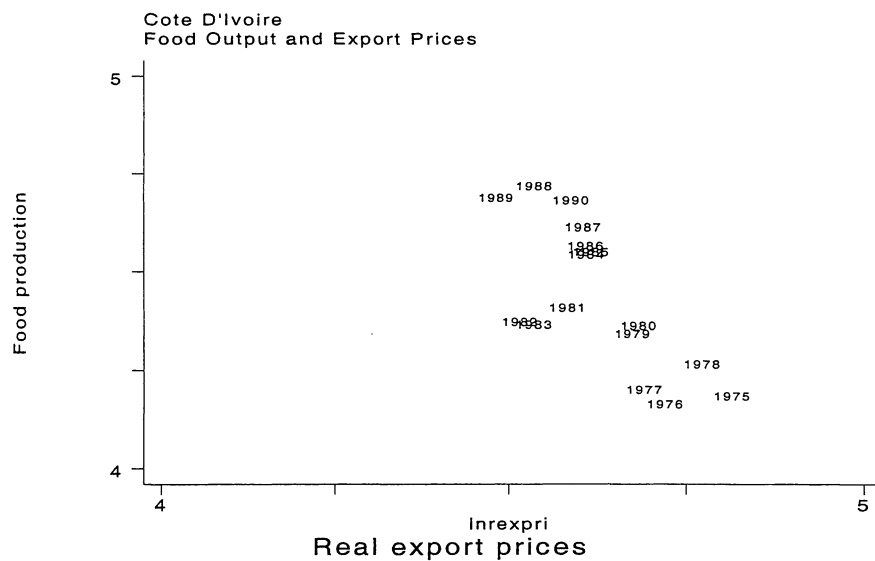
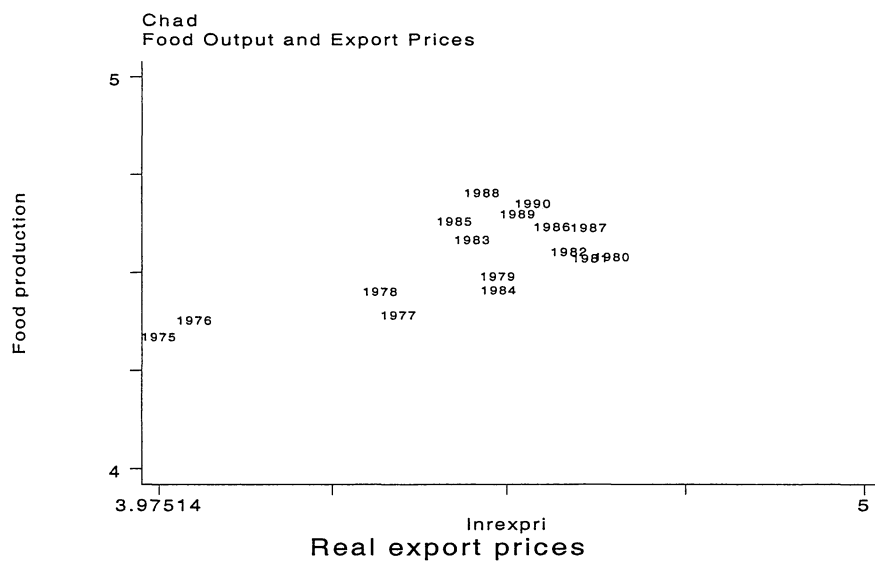


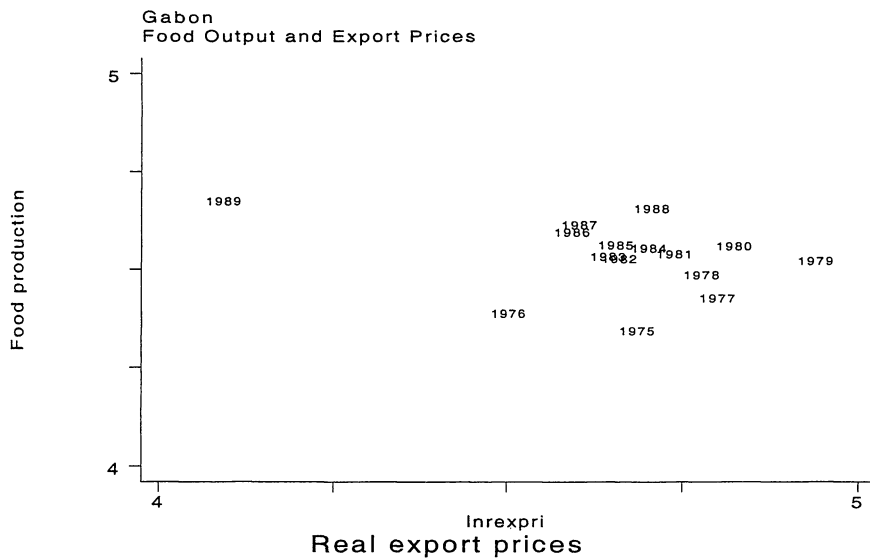


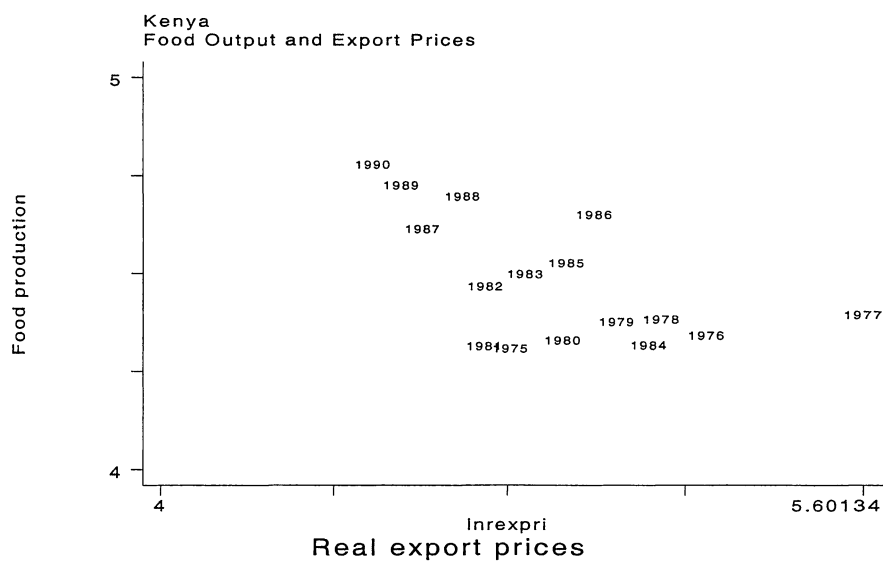
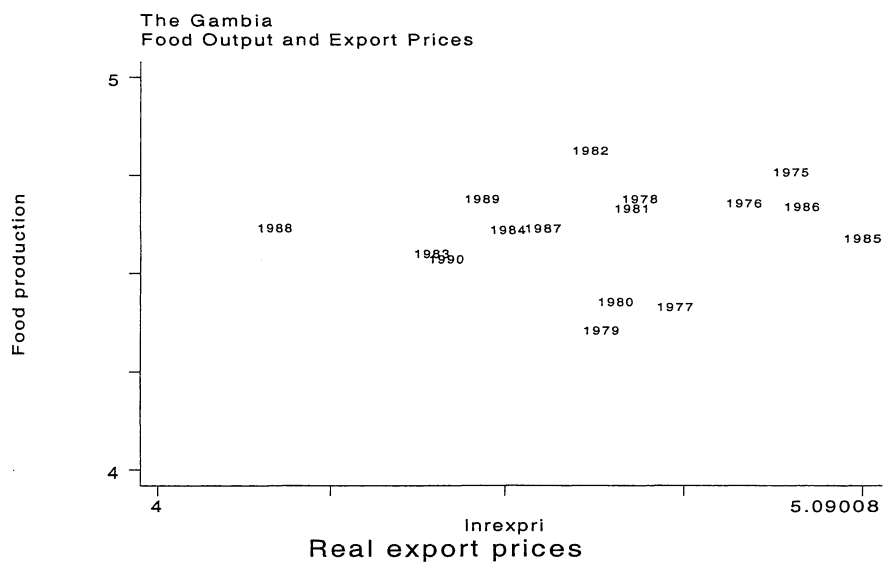




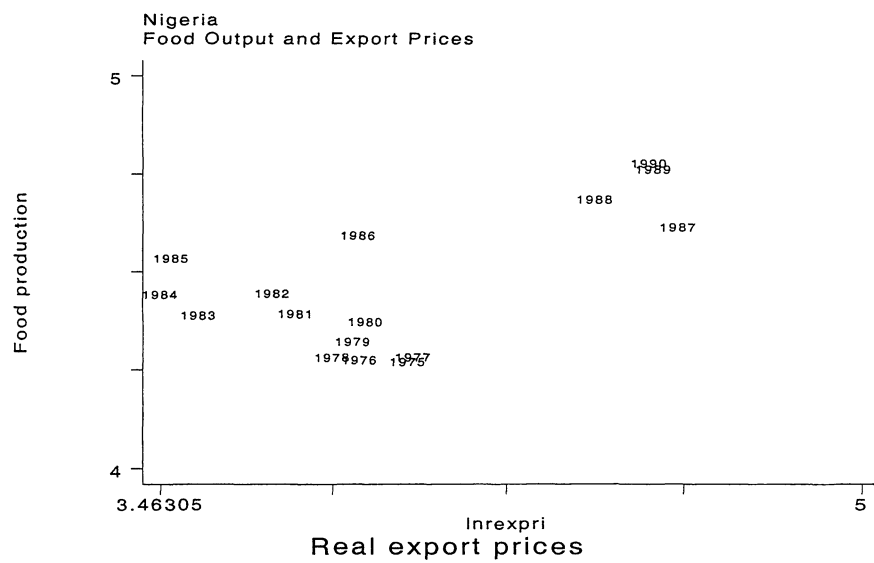
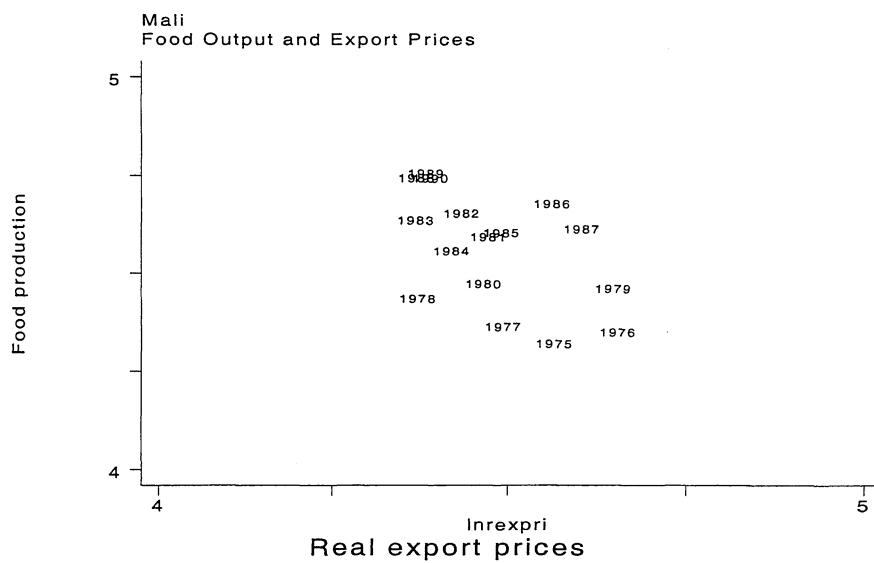
Appendix B. Graphs: food output and export prices, by country

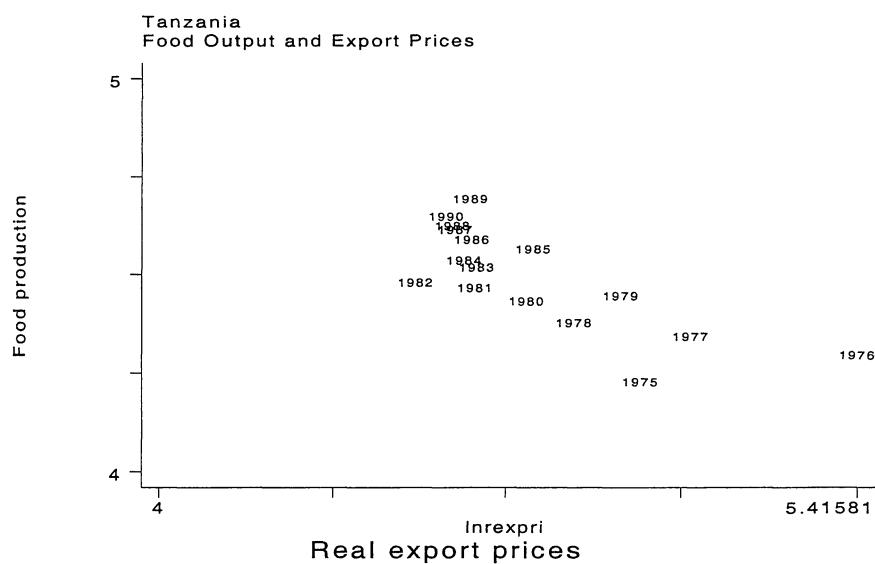
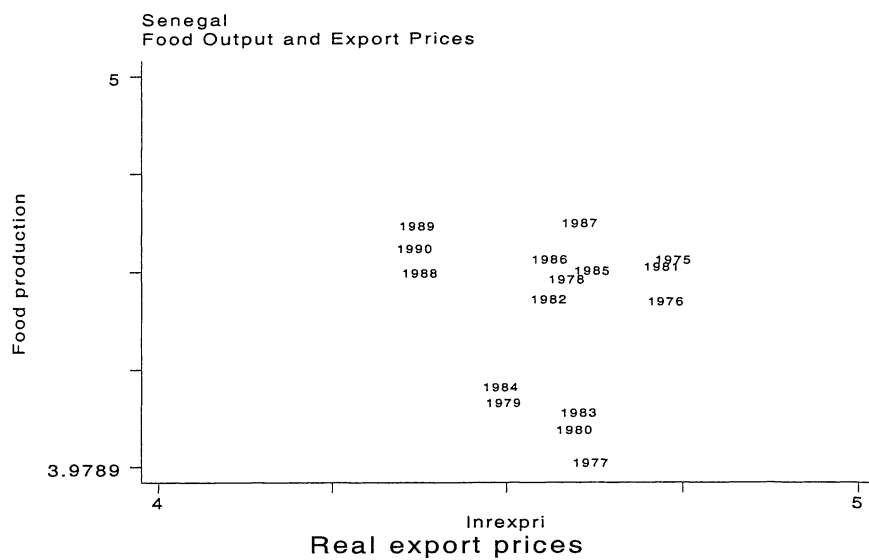












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