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The Impact of Agricultural Policy Reforms on the Output of Selected Crops in Niger

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I. Introduction

In 1984 the Government of Niger with the support of USAID embarked on a program of agricultural policy reform which was designed to "promote agriculture production by meliorating policy constraints to development in the agricultural sector". This paper examines the short-run impact of the reforms on production of three important crops, millet, sorghum, and cowpeas. The methodology consists of estimating a reduced form model of supply and demand for each crop using data for the pre-reform period, applying those results to predict output in the post-reform years, and then comparing predicted and actual output. The results offer weak support for the hypothesis that reforms have had a positive effect on production for these crops at this point.

II. The Rationale for Policy Reform

USAID's Agricultural Sector Development Grant to Niger (ASDG) is an example of the form of conditional sectoral assistance that became common throughout the eighties. Sectoral grant disbursements are made conditional on progress toward structural adjustment, notably liberalization and a reduction in direct government participation in agricultural commerce.[1] Though specifically designed for Niger, the set of reforms was part of a standard package which included removing restrictions on internal trade, disseminating price information, establishing "cereal banks" at the village level, encouraging cooperatives to participate in agricultural input markets, reducing input subsidies, simplifying the export licensing system, and introducing competition in the purchasing procedures used by the government cereal board (OPVN). The anticipated benefits included increased agricultural production, raising rural incomes, improving efficiency in resource use, promoting food security, boosting export revenues, and reducing the deficits of agricultural parastatals. The reforms were introduced in stages beginning in 1985 and continuing through 1990.[2]

In designing the set of policy reforms that constituted conditions precedent for disbursements under ASDG, the project design team noted that Niger's food deficit was primarily due to increasingly severe climatic and soils constraints coupled with rapid population growth. But the project paper also identified a lack of dynamism in the sector which restricted adjustments in technology and production patterns. Sectoral stagnation was

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[1]For a discussion of agricultural policy reforms in Africa see Gellar (1985) and Ndulu (1986).

[2]The grant was later amended to include seed production and range management. These are not considered here.

attributed to "a complex of interrelated institutional and policy constraints that will have to be addressed before Niger can hope to attain a reasonable level of food self reliance".[3] Relieving these constraints through policy reform was thus seen as a necessary though not sufficient condition for engendering agricultural growth. The reforms were constructed to both relieve specific constraints and to establish an environment conducive to increased agriculture productivity.

Five policy and institutional areas were identified for immediate reform:

1. input supply, subsidies, and input pricing;
2. agricultural credit;
3. agricultural price and marketing policies;
4. cross-border trade in grains and livestock; and
5. the role of the private sector and cooperatives.

Policy and institutional shortcomings in these areas were seen to be engendering inefficiencies in sectoral performance by constraining both supply and demand and by introducing distortions in factor and product pricing. Further, they were contributing to public sector inefficiencies through the deficits of parastatals and through the human resource demands placed on public agencies. All five of these areas were seen to offer opportunities for technically simple and fiscally inexpensive reforms that could be tied to sector assistance. This approach contrasts sharply with more costly investment programs to ameliorate sectoral deficiencies, such as bolstering agricultural research and extension, which are traditionally the object of project assistance.[4] Given the budgetary and absorptive constraints faced by Niger, sector aid conditioned on policy reform was attractive to both donor and recipient.[5]

Reforms were intended to promote competition in grain marketing through the liberalization of official marketing and pricing policies and through the increase in the relative share of agricultural outputs marketed by

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[3]USAID, PAAD, Annex H: "Institutional and Policy Constraints on Agricultural Production in Niger", April 1984. Unless otherwise noted all quotations in this section refer to the project paper.

[4]In fact the sectoral grant made explicit the consolidation of the existing public investment program in the agricultural sector as one of its rationales. A good brief discussion of the limits of agricultural project aid is found in Eicher, 1986.

[5]The design and monitoring of appropriate reforms may in fact be quite a complex task which impose a burden on analytical and policy-making capacity and which led to the provision of a technical-assistance component in the ASDG. Reforms also anticipated direct fiscal benefits in the form of reduction of parastatal deficits. On the other hand, the political costs of reform may be substantial and the ability of the government to effectively implement and sustain reforms is open to question. See Herbst (1990) and Thomas and Grindle (1990).

cooperatives and private traders.[6] Liberalization of cross-border trade was expected to increase the demand for cowpeas.[7] The specific reforms with regard to cereals and cowpeas were the liberalization of the marketing of grain by administrative decree, including abolishment of uniform national pricing and the removal of administrative and fiscal impediments to trade; the introduction of a system of tenders and bids in securing government grain reserves; reform of the cooperative sector and increased support for village-level grain storage; and significant reduction of administrative and fiscal controls on border trade. Increased competition would then:

1. Promote increased production and exports of cereals and cowpeas;
2. Reduce the cost of supplying cereals to the urban sector and to northern areas of the country;
3. More effectively support producer prices for cereals and reduce intra-seasonal price variation;
4. Reduce the cost of managing the country's emergency food reserve;
5. Increase farmer incomes and export earnings from agricultural production;
6. Promote interregional trade, particularly with Nigeria;
7. Promote registration of exports; and
8. Promote more cooperative and private trader participation in the supply of agricultural inputs and encourage the evolution of cooperatives as grain marketing and storage intermediaries;

We direct our efforts to devising an empirical test of whether the first of these objectives has been achieved.

III. Objectives and Methodology

This paper sets out a methodology for empirically testing the effects of the reforms on agricultural production by modeling two major sub-sectors (cereals and cowpeas) and then testing whether observations from the early post-reform era support the hypothesized effects of increased production. It is acknowledged that this approach is quite limited. This technique does not directly test the connection between reforms and performance, nor can it identify the success specific reforms may have had in stimulating production; it is intended to complement other direct and more qualitative evaluations of the implementation experience.

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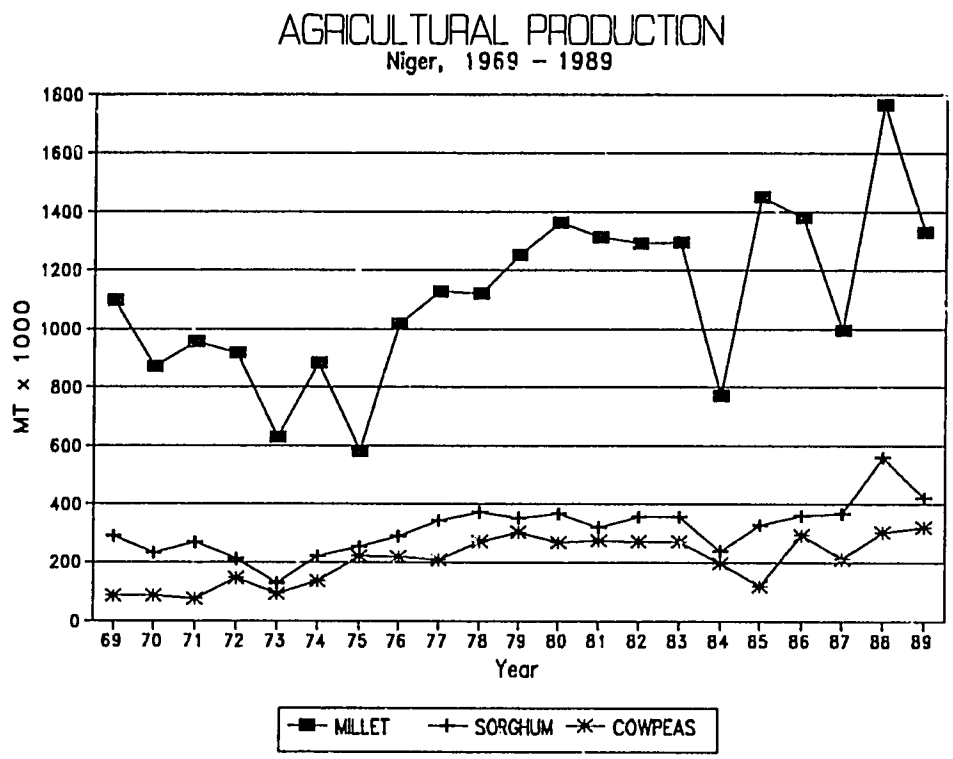
[6]Agricultural input reforms were not expected to necessarily reduce production costs and thus increase output of cereals and cowpeas; reform designers were much more concerned with efficient resource allocation on the input side, so no *a priori* claims of increased use of modern inputs were made.

[7]Reforms in cross-border trade also targeted livestock production and exports.

A complete analysis of ASDG reforms would directly examine their implementation (were trade restrictions effectively alleviated, was price information disseminated, etc.) and their proximate effects (quantities sold through public offerings, amount of cereal stored in "cereal banks") as well as the intended broader objective of increased production and trade. A full evaluation of the reforms would also examine impacts on a wider variety of variables, other crops, trade, and incomes. But it is clear that millet, sorghum, and cowpea output are key variables in assessing the reforms. Millet and sorghum are the main source of cereal consumption and the most important crops in the dominant rainfed sector. Cowpeas are Niger's major export crop. All three were subjected to a variety of governmental restrictions which the reforms sought to alleviate. While not axiomatic that results would be apparent first in production of these crops, that was certainly the expectation of the reform designers.[8]

[8]Note that this was not the case with regard to input use, where the project paper explicitly notes that increased fertilizer use was not a necessary outcome of improved efficiency in resource use.

Figure 1



To make an initial assessment of the effects of the reforms on production we examine the data on the evolution of output since 1969 (See Table 1 and Figure 1). By themselves the data tell a mixed story and it is difficult to sort out any trends or shifts from inter-year fluctuations. By the end of the selected period cowpea output had recovered from the decline experienced in 1984-85, setting an all-time record in 1989. Sorghum production suggests a steady recovery from the poor 1984 season, with record production in 1988 and 1989. The data on millet demonstrate considerably more fluctuation. They do reveal that in four of the five years since reforms were introduced millet production exceeded previous norms, the bumper crop in 1988 surpassing the pre-reform high by thirty percent. All three crops thus offer some evidence of increased production in the post-reform era, but leave open the question of whether one can attribute the strong performances in 1985 and 1986 to reforms which were then at a very early stage.

In any event, such speculations are based upon an incomplete picture. The evaluation of the effects of reforms is bedeviled by the fact that they coincided with changes in various other factors affecting agricultural

TABLE 1
Agricultural Production in Niger, 1969-1989
(Output in thousands of metric tons)

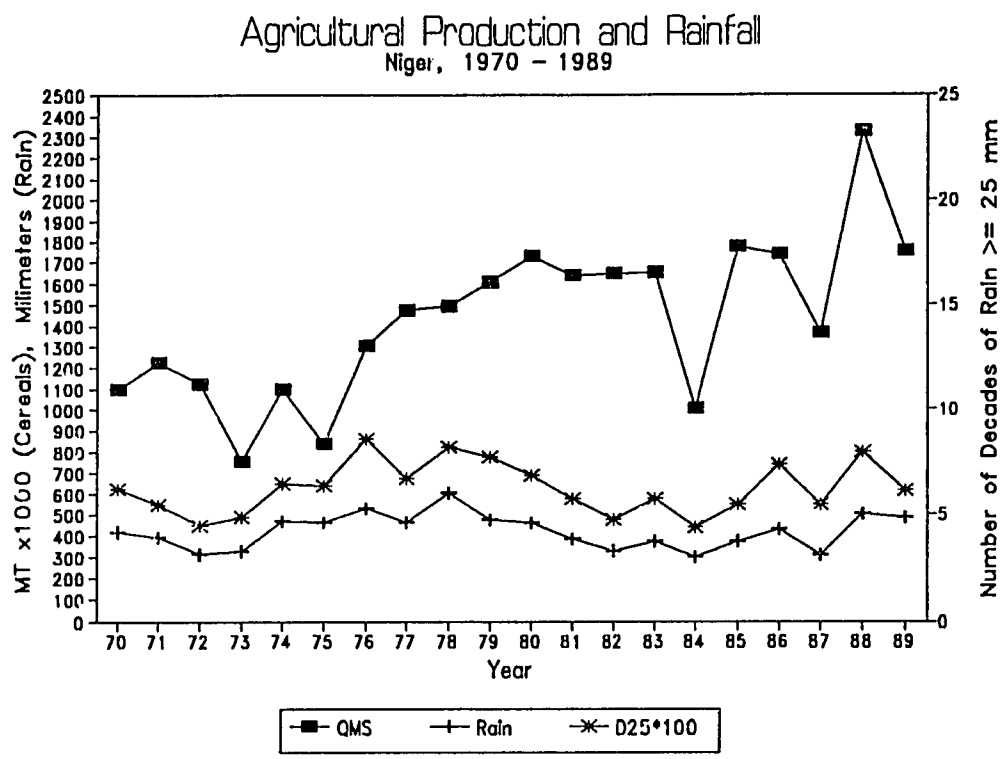
YEAR	MILLET PRODUCTION	SORGHUM PRODUCTION	MILLET AND SORGHUM PRODUCTION	COWPEA PRODUCTION
1969	1095.4	289.3	1384.7	83.3
1970	870.9	230.2	1101.1	84.3
1971	958.9	266.8	1225.7	72.1
1972	918.8	208.4	1127.2	144.1
1973	626.9	126.1	753.0	92.2
1974	882.6	218.9	1101.5	132.7
1975	581.3	253.8	835.1	218.5
1976	1019.1	286.6	1305.7	216.1
1977	1130.3	342.0	1472.3	206.8
1978	1122.6	371.2	1493.8	271.5
1979	1255.2	350.8	1606.0	304.1
1980	1363.6	367.9	1731.5	266.3
1981	1313.9	321.6	1635.5	275.1
1982	1292.5	357.0	1649.5	271.7
1983	1298.3	355.4	1653.7	271.3
1984	771.0	236.4	1007.4	194.8
1985	1449.8	329.2	1779.0	115.3
1986	1383.3	360.1	1743.4	292.9
1987	996.9	365.8	1362.7	208.8
1988	1766.3	560.2	2326.5	301.5
1989	1332.7	421.8	1754.5	320.5
Mean	1115.7	315.2	1430.9	206.9
Std	290.1	90.8	371.5	83.4
Min	581.3	126.1	753.0	72.1
Max	1766.3	560.2	2326.5	320.5

Source: Ministry of Agriculture

output, notably rainfall. One can get some idea of the correlation between production and rainfall by looking at Figure 2 which plots combined millet and sorghum production along with two rainfall statistics. This graph suggests that much of the variance in production can be explained by rainfall. In particular, rainfall seems to explain some of the sharp swings in production since 1984. The analysis of the impact of reforms needs to account for rainfall and other factors such as pest activity, the naira-FCFA exchange rate (which particularly affects the profitability of cowpea production), and other factors that influence the supply and demand for these crops.

To isolate the impact of reforms we have specified models of the markets for millet, sorghum, and cowpeas, using available data on other determinants such as rainfall. These models are estimated econometrically from data for the pre-reform period and then used to predict output in the post-reform years. Observation of actual output in these years that is

Figure 2



significantly greater than what is predicted will lend support to the hypothesis that the reforms have had the anticipated effect on production. An alternative test is carried out by estimating the models using data from all available years while introducing a dummy variable for post-reform years.

The remaining sections of this paper deal respectively with the specification of the models, their econometric estimation, the comparison of actual and predicted output in the post-reform years, and a discussion of the results in light of the qualitative analysis of Niger's reform experience.

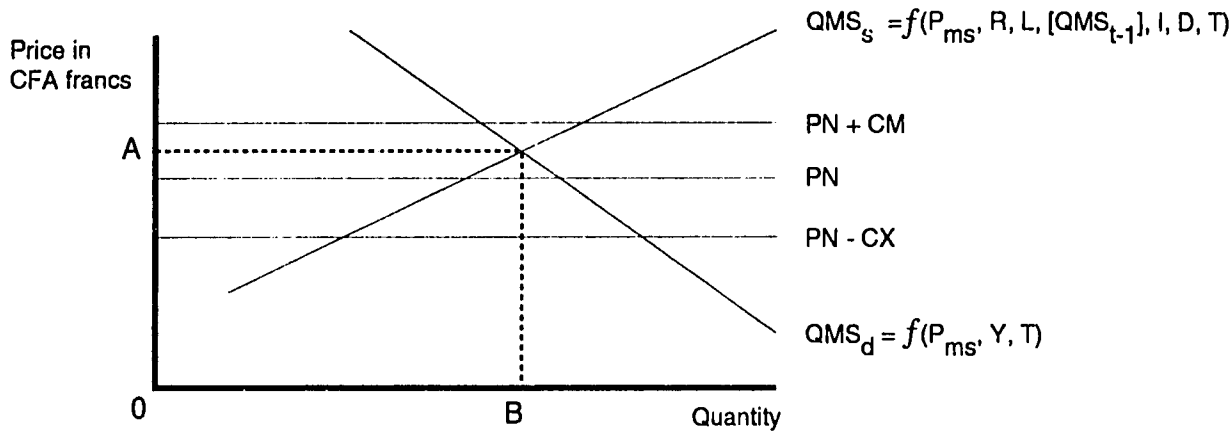
IV. MODELS OF MILLET, SORGHUM, AND COWPEA PRODUCTION

Millet and Sorghum

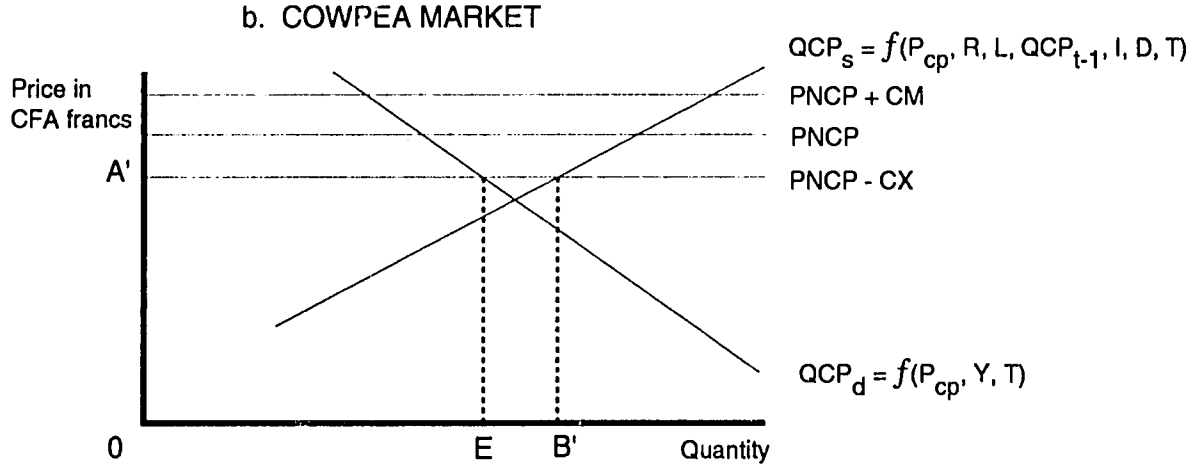
An equation showing the determinants of millet and sorghum output in Niger can be derived from a supply-demand model of the kind illustrated in

FIGURE 3: MODELS OF AGRICULTURAL MARKETS IN NIGER

a. MILLET-SORGHUM MARKET WITH NO IMPORTING



b. COWPEA MARKET



c. MILLET-SORGHUM MARKET WITH IMPORTING

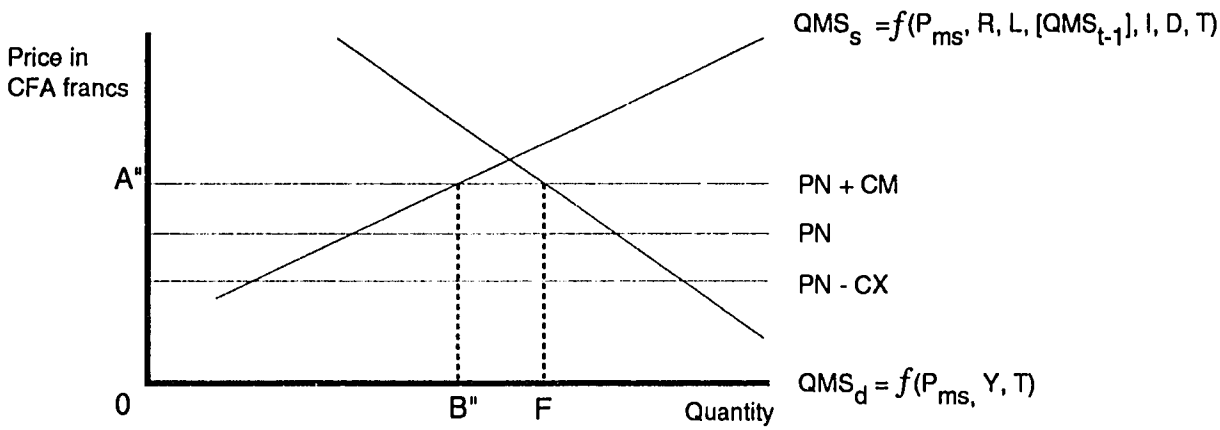


Figure 3a. The quantity supplied (QS) is a function of retail price (P), and series of variables representing the temporal and spatial distribution of rainfall (R), an index of pest activity (L), the previous year's output (Q_{t-1}), input prices (I), distribution costs like transportation and dealers' margins (D), and a trend variable reflecting technological change and other dynamic factors (T). Positive relationships are expected for price, rain, and trend, and inverse relationships between the dependent variable and the other factors. The putative negative effect of lagged output is based on the presumption that high output in one year may exhaust the soil and lower yields in the following year. The quantity demanded (Qd) is a function of retail price (P), real income (Y), and a trend variable reflecting changes in tastes, population and other dynamic factors. The standard inverse relationship is expected for price with positive relationships for income (cereals are presumed to be normal goods) and trend.

The retail price in Nigeria (PN, denominated in FCFA) is assumed independent of the Niger market, in line with the very large size of Nigeria's market in relation to that of Niger. The unit costs of exporting from Niger (CX) and importing into Niger (CM) are assumed to be constant with respect to quantity.

With the configuration of supply, demand, and Nigerian price shown in Figure 3a, no cross-border trade will occur. This situation approximates that found in Niger, at least in the pre-reform period. The retail price in Niger will be that which equates domestic supply with domestic demand, namely OA.[9] This price is higher than what producers could obtain from exporting (PN minus CX), hence no exporting will occur. At the same time the price is lower than what importers would charge (PN plus CM), hence there will be no importing. Substantial devaluations of the naira in recent years have almost certainly caused the FCFA-denominated price PN to have fallen, making imports more attractive. In this case the appropriate model would more closely resemble Figure 3c, the implications of which we discuss later.

The functioning of the millet and sorghum markets can therefore be described by the following system of equations:

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[9]It is assumed here that the operation of the OPVN was too small to have a significant direct effect on price and quantity in the market as a whole. The Project Paper reports that between 1975 and 1983 OPVN local purchases accounted for around 20% percent of marketed output, or just 3% of total production. Much of this activity was directed toward supporting prices in surplus producing regions in an attempt to stabilize prices spatially and intra-seasonally. OPVN was responsible for marketing food aid and a small amount of commercial imports which have not been incorporated into the analysis. As noted above, the major effect of the OPVN monopoly on cereal trade was to dampen competition and increase distribution costs.

Supply: $QMS_s = f(P_{ms}, R, L, Q_{t-1}, I, D, T)$ (1)

Demand: $QMS_d = g(P_{ms}, Y, T)$ (2)

Equilibrium: $QMS_s = QMS_d$ (3)

From this system a single equation can be obtained expressing the quantity supplied (or production) as a function of exogenous determinants only, an equation that can therefore be directly estimated by econometric methods. This equation, which is known as a "reduced form" of the system, is as follows:

$$QMS = h(R, L, QMS_{t-1}, I, D, T, Y) \quad (4)$$

Through promoting competition, the policy reforms in Niger may cause reductions in input prices I and distribution costs D. Hence the equation provides a framework for measuring effects of the policy reforms.

Unfortunately, I and D are not readily measurable. Among the remaining determinants, the same is true of L, the pest index. But a second-best procedure can be used instead. The variables I, D, and L can be dropped, and a truncated version of equation (4) can be estimated from pre-reform data, using only R, QMS_{t-1}, T, and Y as independent variables. As explained above, this estimated equation can then generate annual predictions of millet and sorghum output in the post-reform period. Comparing these predictions with actual output values for those years will provide some evidence about the effects of the reforms.

Cowpeas

The supply-demand model for cowpeas in Niger is shown in Figure 3b. The quantities supplied and demanded have the same determinants as for cereals, but the relationship between the supply and demand curves and the price of cowpeas in Nigeria is such that exports from Niger take place. The price of cowpeas in Niger is thus not determined by the domestic market as in the case of millet and sorghum, but is determined by the Nigerian price (PN) and export costs (CX) including transportation, export taxes, licenses, etc. In the graph the Niger cowpea price is given as OA', Niger production is OB', and exports to Nigeria are EB'.

Since in these conditions the price in Niger is determined by the Nigeria price and export costs, the supply function for cowpeas can be written as:

Supply: $QCP_s = f(PN_{cp}, CX, R, L, QCP_{t-1}, I, D, T)$ (5)

In this equation, all of the independent variables are exogenous, and a direct econometric estimation of the equation will therefore provide unbiased estimates of the relationships between cowpea production and its determinants. In contrast to the cereals market, here Niger demand has no effect on the level cowpea output, but influences only the division of output between exports and domestic sales.

The agricultural policy reforms were intended to reduce exporting costs, input costs, and distribution costs, the effect of which would be to shift supply to the right and increase the quantity produced (and exported). As in the case of cereals, however, data are lacking on these three variables, and so an indirect test of the hypothesis requires estimation of a regression equation based on the remaining variables and comparison of predicted and actual values for the post reform period.

V. ECONOMETRIC ESTIMATION OF THE MODELS

Data

As noted above, the equations to be estimated are:

$$QMS = h\ (R,\ QMS_{t-1},\ T,\ Y\ ) \tag{6}$$

and

$$QCP = f\ (PN_{cp},\ R,\ QCP_{t-1},\ T) \tag{7}$$

Millet and Sorghum are generally acknowledged to be good substitutes in both consumption and production. For the country as a whole millet production tends to dominate, accounting for around three-quarters of combined output. Given the presumed high cross-elasticities of both supply and demand, and the similar agronomic characteristics of the two crops, the effects of the policy reforms on each should be similar. For these reasons the cereals model was estimated on both combined millet and sorghum production and on each crop separately. The production data used are shown in Table 1.

It is obvious that the total annual rainfall is an important if not dominating factor in the generally arid conditions of Niger, but out conversations with agricultural specialists suggested that temporal and spatial distribution were also important and would significantly increase explanatory power. To capture the spatial dimension we included rainfall

data from eight stations located along the zone of intensive agriculture.[10] With regard to temporal (intra-annual) distribution, agronomists report that deficient moisture during certain stages of the plants' development leads to stress and can significantly lower yields. This is particularly true for cereals during the flowering stage with occurs late in the season, and for legumes such as cowpeas during the period when the plant establishes its root system. Unfortunately, we could find no standard measure of temporal distribution nor estimates of critical values for adequate rainfall during different periods.

Following our discussions with agronomists we calculated temporal distribution statistics based on the quantity of rainfall during ten-day periods (*decades*) as reported by the national meteorological service. Since we were trying to capture the likelihood that crops not be subject to stress, we measured the number of *decades* when rainfall exceeded a certain minimum for each rainfall station. Using disaggregated (departmental) data it was determined that 25 mm. of rainfall per *decade* was the critical minimum value for both cereals and cowpeas.[11] We then computed annual (D25) and sub-seasonal measures of temporal distribution by averaging over reporting stations. The variable ERLY25 gauged the adequacy of rainfall during the early part of the rainy season (June and July) while LATE25 does the same for the late part of the season (August and September). The data on these three temporal-distribution variables as well as total annual rainfall are shown in Table 2.

A difficulty presents itself in the choice of the appropriate form of the real income variable (Y) which affects millet and sorghum output from the demand side. The problem with using real gross domestic product (GDP) is that in a basically agrarian economy like Niger, cereals are the main food crop and they constitute an appreciable fraction of GDP. Hence, GDP cannot be said to be statistically independent of millet and sorghum output. We solve this problem by using real <u>nonagricultural</u> GDP as the aggregate income variable in equation (6) (Table 3).

The Nigerian price variable is supposed to be one which is relevant for cowpea producers in Niger. In principle, it should be constructed so as to reflect the real price of cowpeas in Nigeria measured in CFA francs. Ideally we would like to take the price of cowpeas in Northern Nigeria

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[10]Efforts to refine the rainfall variables by weighting according to agricultural shares yielded essentially identical results to the unweighted averages of the eight stations.

[11]Experimentation with the desegregate data consistently showed that using a critical value of 25 mm. per *decade* explained more of the variation in output than 20 mm. or 30 mm. Whether this value has any agronomic significance we are not in a position to judge.

TABLE 2
Rainfall in Niger, 1970-1989[a]

YEAR	Total Annual RAINFALL (in mm.) (Rain)	Total *Decades* with min 25 mm rain (D25)	June/July *Decades* with min 25 mm rain (ERLY25)	Aug/Sep *Decades* with min 25 mm rain (LATE25)
1970	419.3	6.3	2.6	3.5
1971	392.7	5.5	1.8	3.4
1972	316.2	4.5	2.4	2.0
1973	328.2	4.9	2.0	2.8
1974	471.1	6.5	2.8	3.6
1975	463.6	6.4	2.6	3.4
1976	527.5	8.6	3.6	3.4
1977	466.6	6.8	3.0	3.4
1978	604.3	8.3	3.4	3.8
1979	473.4	7.8	4.3	2.9
1980	459.8	6.9	3.9	2.6
1981	383.4	5.8	2.6	2.6
1982	329.3	4.8	1.6	3.1
1983	372.9	5.8	2.5	2.9
1984	300.0	4.4	1.9	2.0
1985	374.0	5.5	1.8	3.6
1986	430.3	7.4	3.3	3.8
1987	308.9	5.5	1.9	3.0
1988	505.8	8.0	3.4	4.6
1989	482.4	6.1	2.3	3.8
MEAN	420.5	6.3	2.7	3.2
STD DEV	82.3	1.3	.8	.6
MIN	300.0	4.4	1.6	2.0
MAX	604.3	8.6	4.3	4.6

a. All data are unweighted averages for the following reporting stations: Birni-Nkonni, Tillabery, Niamey, Dosso, Tahoua, Keita, Maradi, and Zinder.

Source: National Meteorological Service

measured in naira, convert to CFA francs using the relevant exchange rate (i.e., the parallel market rate), and then deflate using the general cost-of-living index for Niger (since all monetary variables in our models are defined in real terms). Although we have been able to obtain information on the parallel exchange rate and a general cost-of-living index for Niger, our efforts to find the necessary data on cowpea prices in Nigeria were unsuccessful. We therefore use a proxy for cowpea prices, in the form of a general index of food prices in Nigeria. The behaviorally relevant variable -- the real CFA franc-denominated price of food in Nigeria (PFN) -- is derived from these series. This index and its determinants are shown in Table 3.

We had to determine the cutoff year for the pre-reform period. The policy reforms under ASDG were to be phased in throughout the time frame of the program, beginning in 1985. An argument can be made that among the most important steps toward full implementation was the government's declared commitment to implementing reforms, manifested by signing the grant agreement and the government decree announcing the liberalization of grain marketing and elimination of the policy of uniform national pricing. Thus, if reforms took hold early it would be appropriate to use 1985 as a cutoff. On the other hand, the effective implementation of specific reforms such as the reduction of administrative and fiscal controls on cross-border trade, successful execution of an auction market by the OPVN, and broadcast of market prices were much slower to be accomplished. This would argue for a later cutoff date such as 1987, by which time most reforms were at least in the process of being enacted. A final argument can be made that even effectively operating reforms would take several years before the impact could be discerned. This offers a fine *ex ante*

TABLE 3
Selected Economic Series for Niger, 1970-1989

YEAR	Niger Non-Ag GDP at 1980 Prices[a] (NOAGGDP)	Nigeria Food Price Index[b] (NFPI)	CFA-Naira Parallel Market Exchange Rate[c] (CFAN)	All-Item Niger Consumer Price Index[d] (NCPI)	Real CFA-Denominated Nigeria Food Price Index[e] (PFN)
1970	139.6	20.4	162.7	35.0	94.81
1971	150.6	25.7	234.5	36.4	165.55
1972	154.5	26.1	267.3	39.9	174.86
1973	168.6	25.5	270.2	44.8	153.74
1974	158.6	30.6	270.2	46.2	178.89
1975	195.0	43.6	241.9	50.4	209.40
1976	214.6	54.6	279.9	62.3	245.54
1977	217.7	73.0	236.1	77.0	223.85
1978	246.7	86.0	198.4	85.0	200.75
1979	294.4	93.0	203.4	92.0	205.60
1980	308.0	100.0	231.7	100.0	231.73
1981	316.4	126.0	296.9	124.0	301.73
1982	315.5	137.0	288.2	137.0	288.17
1983	280.6	169.0	200.2	134.0	252.45
1984	228.1	242.0	140.1	145.0	233.90
1985	221.7	251.0	117.3	144.0	204.54
1986	232.9	252.0	85.5	139.0	155.05
1987	232.0	273.0	68.0	130.0	142.80
1988	227.9	420.0	49.0	128.0	160.79
1989	229.8	577.7	31.4	124.3	146.14
MEAN	226.7	151.3	193.7	93.7	198.51
STD DEV	55.4	147.7	84.6	41.4	51.79
MIN	139.6	20.4	31.4	35.0	94.81
MAX	316.4	577.7	296.9	145.0	301.73

[a] Sources: 1970-1986 from World Bank, World Tables 1988-89; 1987-89 from Jamal Kibbi, World Bank.
[b] Source: United Nations, Statistical Yearbook and Monthly Bulletin of Statistics.
[c] Source: Pick's Currency Yearbook, International Financial Statistics (IMF), and Ministry of Agriculture.
[d] Source: United Nations, Statistical Yearbook and Monthly Bulletin of Statistics.
[e] PFN = (NFP x CFAN) / NCPI

rationalization should this analysis show no positive effects from reforms, but hardly guides us as to how to segment the sample at this time.

Finally, initial examination of the data using scatter plots revealed several outliers. The most extreme cases were in 1973-75, coinciding with the end of the devastating drought years of that era. This led us to estimate the model both using and excluding those years.

Estimates for Millet and Sorghum

The full version of equation (6) included six independent variables: annual rain (RAIN), early-season *decades* with adequate rain (ERLY25), late-season *decades* with adequate rain (LATE25), lagged output (QMSLAG), nonagricultural GDP (NOAGGDP), and a trend term (T). Using least-squares multiple regression, a linear model was estimated for millet and sorghum combined (QMS) and then separately for millet (QMIL) and sorghum (QSOR). The results of the regressions are shown in Tables 4-6.[12]

Estimating the full model for the 1970-1986 period using the combined millet and sorghum data (Table 4, column a) the variables for total and early season rainfall yielded little explanatory power, as was also the case for the variable for lagged output. In subsequent estimations these variables were dropped with little loss of predictive power.[13] Our abbreviated model (column b) yields a reasonably good fit (R^2 = .715 and adjusted R^2 = .680) with both the early rainfall and nonagricultural GDP being statistically significant. Dropping the three drought years (column c) yields a better fit, as expected, with little effect on the values or significance levels of the coefficients. Truncating the sample in 1984 (under the premise that reforms took effect early, column d) while still excluding the drought years does seem to yield a significantly better fit, though it also results in substantial changes in the estimated coefficients; in this case the coefficient for early rains is no longer significant while the trend term takes on a negative value. Finally, our direct test of the effect of the reforms estimates the equation for the entire period (1970-89) using a dummy variable for the post-reform years, here assumed to be 1987-89 (column e). This structure estimates the effects of the reforms as an absolute shift in output holding the influence of the other variables constant. The resulting estimates of coefficients and their significance levels are similar to those in the full and abbreviated models, with the reform dummy being positive though not statistically significant.

Though our interest in these estimates is principally to find an efficient predictor that will enable us to compare predicted and actual values in the post-reform years (except in the case of the direct test

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[12]In an effort to capture non-linearities, log-linear forms of the equations were estimated with similar results as regards the signs and significance levels of the regression coefficients though yielding less overall explanatory power. These are shown in Appendix Table A-1.

[13]Given the obvious correlation among total rainfall and our construction of the variables for sufficient early and late rainfall we also tested for group entry of the deleted rainfall variables. In all cases the F statistic for the dropped variables was far from the critical level.

TABLE 4
Estimates of Regression Equations for Combined Millet and Sorghum

Variable	(a) Full Model (1970-86)	(b) Abbrev. Model (1970-86)	(c) Excluding Drought (1970-86)	(d) Excluding Drought (1970-84)	(e) Reform Dummy (1970-89)
LATE25	315.68 (174.69)	191.25* (96.35)	203.31* (71.14)	81.[illegible] (59.20)	278.66** (90.84)
TREND	14.17 (18.23)	17.79 (14.98)	11.45 (10.68)	-27.74* (13.07)	17.07 (15.85)
NOAGGDP	3.16* (1.73)	3.278* (1.274)	2.769* (0.922)	5.06** (0.890)	3.45* (1.35)
RAIN	-1.68 (1.78)				
ERLY25	147.04 (141.88)				
QMSLAG	.030 (.262)				
REFORM					70.77 (211.00)
Constant	-185.15 (517.67)	-127.28 (405.25)	74.21 (299.88)	208.90 (208.09)	-430.94 (398.43)
Cases	18	18	15	13	21
R^2	.715	.680	.760	.886	.732
Adjst R^2	.545	.607	.689	.843	.661
Deg Frdm	10	13	10	8	15
Durb-Wat		2.00	2.70	2.89	2.13

Numbers in parentheses below the coefiicients are standard errors. Significance levels are indicated by:
*** significant at .10 level.**
**** significant at .05 level.**
***** significant at .01 level.**

using the reform dummy), it is interesting to interpret the coefficients. According to the abbreviated model, each extra ten-day period in August or September when rainfall exceeds 25 mm. adds around 200 thousand metric tons to millet and sorghum production.[14] This is a substantial marginal effect given that cereal production averaged 1,116 thousand metric tons over the

[14]In the full model late rainfall has even a greater impact at the margin (each extra *decade* of more than 25 mm. adding over 300 metric tons) while the marginal impact of early rainfall is about half that. It is important to note, however, that the standard errors of both these coefficients is quite high relative the value of the coefficients, rendering the confidence interval containing their true value quite large. Further, these are truly estimates of temporal distribution, holding total rainfall constant; the coefficient for total rainfall is negative, though not significantly different from zero.

TABLE 5
Estimates of Regression Equations for Millet

Variable	(a) Full Model (1970-86)	(b) Abbrev. Model (1970-86)	(c) Excluding Drought (1970-86)	(d) Excluding Drought (1970-84)	(e) Reform Dummy (1970-89)
LATE25	278.77* (151.32)	135.81 (85.18)	150.29* (66.09)	31.11 (48.11)	208.63** (79.16)
TREND	11.68 (15.79)	16.09 (13.24)	10.83 (9.93)	-27.72* (10.62)	15.61 (13.81)
NOAGGDP	2.63 (1.48)	2.385* (1.126)	2.023* (0.857)	4.280** (0.723)	2.523* (1.175)
RAIN	-1.98 (1.56)				
ERLY25	150.46 (122.60)				
QMILLAG	-0.064 (.269)				
REFORM					-18.53 (183.88)
Constant	-0.091 (443.54)	-31.42 (358.25)	106.49 (278.57)	237.68 (169.10)	-283.86 (347.21)
Cases	18	18	15	13	21
R^2	.677	.620	.688	.878	.667
Adjst R^2	.483	.533	.594	.833	.578
Deg Frdm	10	13	10	8	15
Durb-Wat		2.05	2.60	2.85	2.13

Numbers in parentheses below the coefiicients are standard errors. Significance levels are indicated by:
*** significant at .10 level.**
*** significant at .05 level.**
**** significant at .01 level.**

period. Each extra billion FCFA of real nonagricultural GDP adds aroundthree thousand tons to production, according to the supply-demand model as the result a demand stimulus. The trend term is positive, but not statistically significantly different from zero, which suggests that there was no significant net upward or downward trend attributed to technological and consumer taste factors as represented by this term.

Given the dominance of millet in the combined cereals production, it is not surprising that the results for millet alone are quite similar (Table 5). The fit of the estimates on millet are somewhat poorer than for the combined estimate, but the signs, magnitudes, and significance levels of the estimated coefficients are all similar. Only in the direct test of the reforms (column e) do we find an interesting discrepancy; the reform

TABLE 6
Estimates of Regression Equations for Sorghum

Variable	(a) Full Model (1970-86)	(b) Abbrev. Model (1970-86)	(c) Excluding Drought (1970-86)	(d) Excluding Drought (1970-84)	(e) Reform Dummy (1970-89)
LATE25	52.55* (28.46)	67.65¥ (16.30)	53.03¥ (11.10)	50.82¥ (14.96)	70.02¥ (16.41)
TREND	2.25 (2.90)	1.19 (2.39)	0.62 (1.67)	-0.02' (3.30)	1.46 (2.86)
NOAGGDP	0.511* (0.278)	0.577' (0.248)	0.746¥ (0.144)	0.781¥ (0.225)	0.93¥ (0.244)
RAIN	0.14 (0.27)				
ERLY25	-1.83 (22.25)				
QSORLAG	0.392* (.214)	0.426' (0.193)			
REFORM					89.30' (38.11)
Constant	-174.21 (80.37)	-180.55 (75.01)	-32.28 (46.78)	-28.78 (52.58)	-147.08 (71.96)
Cases	18	18	15	13	21
R^2	.847	.838	.873	.867	.853
Adjst R^2	.756	.785	.835	.818	.814
Deg Frdm	10	12	10	8	15
Durb-Wat		2.61	2.33	2.29	2.09

Numbers in parentheses below the coefiicients are standard errors. Significance levels are indicated by:
*** significant at .10 level.**
' significant at .05 level.
¥ significant at .01 level.

dummy takes on a small negative value, though it remains statistically insignificant.

The estimates on sorghum alone also yielded similar results, though with substantially better fit (Table 6). Once again, the total and early rainfall variables added little and were dropped in subsequent estimates. Unlike the case of millet, however, sorghum's lagged output coefficient was significant, though with a positive sign, contrary to what had been predicted. Also, the post-reform year dummy is positive and significant at the .01 level (column e). According to the estimate of the abbreviated model, each *decade* of sufficient late-season rain adds 65 thousand tons to

sorghum production,[15] each additional billion FCFA of real nonagricultural GDP adds a little less than a thousand tons through the demand stimulus, while there appears to be no significant trend effect. When run on the entire period, the model estimates that production in the post-reform years was 90 thousand tons higher than otherwise when the effect of the other variables is taken into account.

Estimates for Cowpeas

Regression estimates of equation (7) are presented in Table 7. Annual cowpea production is linearly regressed on six independent variables: annual rain (RAIN), early-season *decades* with adequate rain (ERLY25), late-season *decades* with adequate rain (LATE25), lagged output (QCPLAG), our proxy for Nigerian cowpea prices (PFN), and a trend term (T).[16]

As in the case of the millet-sorghum model, the regression estimates of the cowpea equation show some of the independent variables to be consistently weak as predictors of cowpea output (column a). In contrast to the cereals case and as predicted by agronomists, the regression coefficients show that early rains are important for the cowpea crop while late-season rains seem to have almost no effect. Total annual rainfall and lagged output added almost no explanatory power and they, along with the variable for late rains were omitted from subsequent estimations.[17] Our abbreviated model (column b) again yields a reasonably good fit (R^2 = .815 and adjusted R^2 = .772). All three independent variables are significantly different from zero, TREND and PFN at the .05 level and ERLY25 at the .01 level. Dropping the drought years had little effect on the statistical estimates (column c), though truncating the data so as to lengthen the post-reform period did improve fit (column d). The direct test of the reforms using the post-reform dummy variable yielded coefficients and significance levels very similar to the other estimates (column e). The post-reform year variable is positive, though not significantly different from zero.

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[15]This is about the same relative impact as in the case of millet, suggesting at least agronomic similarities.

[16]As in the case of cereals, the log linear estimate for cowpeas yielded broadly similar results to the linear models. It did not, however, manifest a deterioration in the fit as was the case in cereals. The results are shown in Appendix Table A-1, column d.

[17]Once again, tests on the excluded variables show that as a group they add no significant explanatory power, though caution must be used when interpreting the remaining rainfall variable, ERLY25, because of its correlation with total rainfall.

TABLE 7
Estimates of Regression Equations for Cowpeas

Variable	(a) Full Model (1970-86)	(b) Abbrev. Model (1970-86)	(c) Excluding Drought (1970-86)	(d) Excluding Drought (1970-84)	(e) Reform Dummy (1970-89)
LATE25	-1.18 (39.27)				
TREND	6.99* (3.39)	6.36* (2.25)	6.48* (2.51)	8.49* (3.33)	6.70* (2.31)
PFN	0.769* (0.386)	0.617* (0.220)	0.581* (0.239)	0.477 (0.280)	0.591* (0.226)
RAIN	-0.04 (0.37)				
ERLY25	63.28* (9.37)	56.01** (12.17)	55.96** (13.35)	43.27** (10.71)	53.57** (11.83)
QCPLAG	-0.15 (0.29)				
REFORM					52.62 (40.44)
Constant	-140.32 (97.01)	-134.48 (51.36)	-127.97 (59.98)	-84.39 (52.98)	-125.58 (51.11)
Cases	18	18	15	13	21
R^2	.820	.815	.801	.891	.813
Adjst R^2	.713	.772	.742	.850	.763
Deg Frdm	10	13	10	8	15
Durb-Wat		2.33	2.10	1.92	2.35

Numbers in parentheses below the coefiicients are standard errors. Significance levels are indicated by:
*** significant at .10 level.**
**** significant at .05 level.**
***** significant at .01 level.**

Interpreting the estimates of the coefficients indicates that each *decade* of adequate rainfall in June or July raising cowpea output by around 55 thousand tons.[18] A positive trend accounts for an annual increase of around 6 thousand tons when the effects of other variables are taken into account. Since in our model demand is exogenous, this effect is solely attributed to the supply side, suggesting improved technology and increased adoption of cowpeas as a cash crop. Finally, an increase in one unit in the real Nigerian food price index (PFN) raises Niger cowpea output by 600 tons. Since this index is scaled arbitrarily, this manner of describing the responsiveness of supply to price is not particularly illuminating.

[18]Since average cowpea production over the period was 207 thousand tons, this demonstrates the importance of satisfactory early rains for cowpeas.

The responsiveness is better expressed in the familiar terms of the price elasticity of supply. At the means of the two relevant variables (cowpea output and the Nigerian price index) the price-elasticity of supply equals 0.633, which is a plausible figure.[19]

It should be noted that this estimate of the price elasticity of cowpea supply provides useful information for assessing the impact of the relative depreciation of the naira (in the parallel market) on the Niger economy. Since the price relevant for Niger cowpea producers is, according to our model, directly proportional to the market exchange rate (expressed as CFA francs per naira), a reduction in that rate due to a weakening of the naira will depress output to the degree indicated by the price-elasticity of supply. Hence, a ten percent depreciation of the naira is equivalent to a ten percent decrease in price and can be expected to cause a 6.3% reduction in cowpea output in Niger.

VI. EVALUATING THE EFFECTS OF POLICY REFORMS

Estimates of the millet-sorghum and cowpea equations succeed in explaining a major part of the annual fluctuations in output. This set of equations can therefore be used with some confidence to generate counterfactual predictions of what would have happened beginning in 1987 (or 1985) if no policy reforms had been instituted. We apply the results of the estimated equations to generate a series of predicted values and then compare those to actual output for pre- and post-reform years. Since the regression equations are estimated from pre-reform years, the differences between actual and predicted values (the residuals) in the post-reform years should reflect the effects of the policy reforms (as well as the effects of other factors omitted from the equations). By testing the hypothesis that the post-reform residual is greater than zero (by

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[19]The mean value of the constructed price index from 1970-1986 is 207.1 while the mean value of cowpea production during that period is 201.75. Using the formula for elasticity:

$$E_0 = (\delta Q/\delta P) * (P/Q)$$

where $\delta Q/\delta P$ is estimated by the regression coefficient for cowpeas and P and Q are the relevant means, we get:

$$E_0 = 0.617 * (207.09 / 201.75)$$
$$= 0.633$$

This indicates that a ten percent increase in the real price of cowpeas (denominated in FCFA) results in a 6.33% increase in production. We know of no independent estimates of supply elasticity for this crop in West Africa, but this figure is well within the range of those estimated for cash crops in West Africa (see Bond 1983).

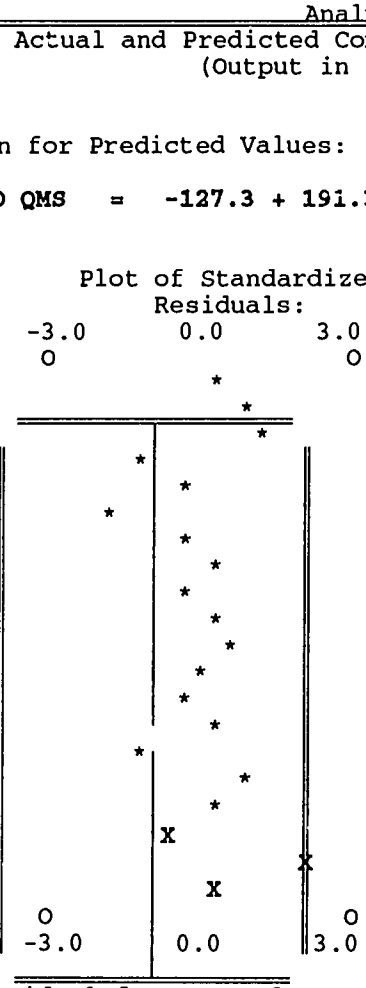
TABLE 8

Analysis of Residuals

Actual and Predicted Combined Millet and Sorghum Production
(Output in thousand of metric tons)

Equation for Predicted Values:

PRED QMS = -127.3 + 191.3*LATE25 + 17.8*TREND + 3.28*NOAGGDP



Year	Actual QMS (a)	PRED QMS (b)	RESID (c)
1970	1101.1	1017.5	83.6
1971	1225.7	1047.4	178.3
1972	1127.2	815.0	312.2
1973	753.0	1022.5	-269.5
1974	1101.5	1174.8	-73.3
1975	835.1	1264.1	-429.0
1976	1305.7	1346.2	-40.5
1977	1472.3	1374.1	98.2
1978	1493.8	1558.7	-64.9
1979	1606.0	1565.5	40.5
1980	1731.5	1580.0	151.5
1981	1635.5	1625.4	10.1
1982	1649.5	1735.8	-86.3
1983	1653.7	1591.4	62.3
1984	1007.4	1269.7	-262.3
1985	1779.0	1577.3	201.7
1986	1743.4	1655.7	87.7
1987	1362.7	1527.1	-164.4
1988	2326.5	1842.3	484.2
1989	1754.5	1698.9	55.6

* = Residual for pre-reform years.
X = Residual for post-reform years.

Residuals Statistics:

Pre-reform years (1970-1986)

	Min	Max	Mean	Std Dev	N
PRED	815.04	1735.83	1365.96	274.69	17
RESID	-429.03	312.16	-0.00	188.24	17

Post-reform years (1987-89)

PRED	1527.14	1842.27	1689.45	157.78	3
RESID	-164.44	484.23	125.12	329.88	3

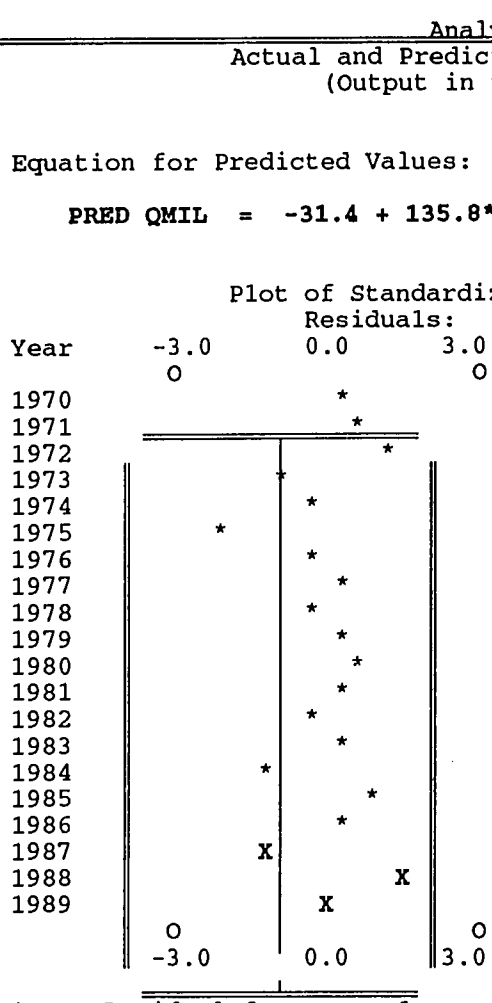
definition the known value of the residuals for the pre-reform years) we have a statistical test of the effects of reforms.[20]

[20]Once data is available for five post-reform years a more straightforward test of the equality two regression equations can be applied, since this test requires that the number of additional observations (post-reform years) exceed the number of explanatory variables.

TABLE 9
Analysis of Residuals
Actual and Predicted Millet Production in Niger
(Output in thousand of metric tons)

Equation for Predicted Values:

PRED QMIL = -31.4 + 135.8*LATE25 + 16.1*TREND + 2.38*NOAGGDP



Year	Actual QMS (a)	PRED QMS (b)	RESID (c)
1970	870.9	792.9	78.0
1971	958.9	818.2	140.7
1972	918.8	656.9	261.9
1973	626.9	808.4	-181.5
1974	882.6	919.5	-36.9
1975	581.3	988.4	-407.1
1976	1019.1	1051.3	-32.2
1977	1130.3	1074.7	55.6
1978	1122.6	1210.9	-88.3
1979	1255.2	1221.9	33.3
1980	1363.6	1236.5	127.1
1981	1313.9	1272.6	41.3
1982	1292.5	1354.4	-61.9
1983	1298.3	1253.3	45.0
1984	771.0	1025.4	-254.4
1985	1449.8	1246.9	202.9
1986	1383.3	1306.7	76.6
1987	996.9	1218.8	-221.9
1988	1766.3	1445.7	320.5
1989	1332.7	1347.6	-14.9

* = Residual for pre-reform years.
X = Residual for post-reform years.

Residuals Statistics:

	Min	Max	Mean	Std Dev	N
Pre-reform years (1970-1986)					
PRED	656.87	1354.43	1072.88	212.77	17
RESID	-407.14	261.93	-0.00	166.41	17
Post-reform years (1987-89)					
PRED	1218.78	1445.77	1337.37	113.84	3
RESID	-221.88	320.53	27.93	273.72	3

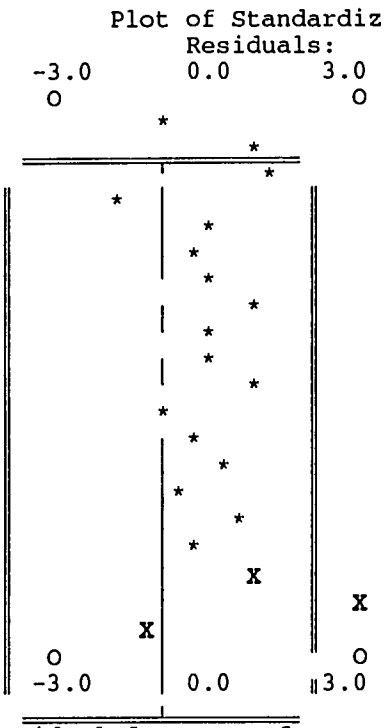
Millet and Sorghum

Column (a) of Table 8 shows actual levels of combined millet and sorghum output in 1970-89. Column (b) shows output predicted with the regression equation using late rainfall, nonagricultural GDP, and a trend factor. The difference between actual and predicted values, the residual, is shown in column (c). Along side the table we present a standardized

TABLE 10
Analysis of Residuals
Actual and Predicted Sorghum Production in Niger
(Output in thousand of metric tons)

Equation for Predicted Values:

PRED QSOR = -180.6 + 67.7*LATE25 + 1.19*TREND + 0.58*NOAGGDP + 0.43*QSORLAG



Year	Actual QMS (a)	PRED QMS (b)	RESID (c)
1970	230.2	261.2	-301.0
1971	266.8	235.1	31.7
1972	208.4	161.1	47.3
1973	126.1	196.3	-70.2
1974	218.9	215.9	3.0
1975	253.8	260.7	-6.9
1976	286.6	288.0	-1.4
1977	342.0	305.0	37.0
1978	371.2	371.9	-0.7
1979	350.8	353.8	-3.0
1980	367.9	337.2	30.6
1981	321.6	350.6	-29.0
1982	357.0	365.4	-8.4
1983	355.4	344.5	10.8
1984	236.4	255.5	19.2
1985	329.2	312.3	16.9
1986	360.1	367.9	-7.8
1987	365.8	331.0	34.8
1988	560.2	442.2	118.0
1989	421.8	468.0	-46.2

* = Residual for pre-reform years.
X = Residual for post-reform years.

Residuals Statistics:

	Min	Max	Mean	Std Dev	N
Pre-reform years (1970-1986)					
PRED	161.09	371.85	293.08	65.55	17
RESID	-70.20	47.31	-0.00	28.78	17
Post-reform years (1987-89)					
PRED	331.01	466.03	413.75	72.80	3
RESID	-46.23	118.01	35.52	82.12	3

plot of the residuals. One notes a fairly random distribution around zero to the pre-reform residuals, as would be hoped for in the absence of any econometric problems.

In two of the three post-reform years the residual is positive, though only in 1988 when actual output exceeded predicted by almost 500 tons is it

significantly different from zero at the .95 level.[21] In that year the late rains were better than in any other year analyzed (Table 2), so predicted output, which takes account of these rains, was at an all-time high. But actual output exceeded even this exceptional figure. The positive residual for 1989 is more modest (55 thousand tons) while that for 1987 was negative (-164 thousand tons). The mean residual for the post-reform years is 125 thousand tons, though it is not significantly different from zero. Other estimates of the combined millet-sorghum equation (including all six variables, excluding drought years, and log-linear form) yielded similar results with respect to the residuals when the reforms were assumed to have taken effect starting in 1987. These results are consistent with the direct test using a dummy variable for the reform years where a positive though statistically insignificant effect was discovered.

When millet and sorghum are separated an important contrast emerges (Tables 9 and 10). In the case of millet the initial impact of reforms in 1987 appears to be strongly negative, followed by impressive positive results in 1988 and almost no effect in 1989. Needless to say, the mean residual for those years is small (28 thousand tons, about 2 percent of actual output during those years) and not significantly different from zero. The case of sorghum suggests a considerably different picture wherein the residual for 1987 is modestly positive, 1988 strongly positive, and 1989 negative. Though the mean residual for the post-reform years (36 thousand tons, 8 percent of actual output) is not statistically different from zero, these results suggest that our assumption that millet and sorghum would respond similarly to reforms may not be true.[22]

What explains the patterns observed and the different response of millet and sorghum output? In particular, are there other factors besides the reforms that are unrepresented in our estimated equations and which might have some bearing on the results. One explanation offered for the initially observed negative residual for the combined estimate in 1987 was pest attacks. Aware that locusts, grasshoppers, and other pests are often blamed for production shortfalls in Niger, we attempted to incorporate this factor in our econometric model, but were unable to assemble a relevant

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[21]We need to reiterate that searching for individual years where residuals are significantly positive is not a very useful guide; our test is to compare all post-reform residuals against the hypothesis that their mean is equal to zero.

[22]Though we decided to analyze residuals using the best overall fit without excluding years, we should report that all other estimates of the sorghum equation yielded even more impressive positive residuals. For example, the full model (including all three rain variables in addition to trend, nonagricultural GDP, and lagged output) shows positive effects in all three years with a mean residual of 93 thousand tons, more than 20 percent higher than predicted during the post-reform period.

series extending back to 1970. Information on a shorter period was, however, obtained. An analyst associated with the Famine Early Warning System (FEWS) offers the following assessments of pest damage in Niger, using a scale going from 1 (no significant damage) to 5 (severe damage).[23]

1985	1
1986	5
1987	4
1988	1
1989	1

Hence, pest damage may indeed explain an appreciable part of the negative residual for millet in 1987. We have been unable to determine whether such damage would be likely to affect millet and not sorghum.

Another factor we have already alluded to and much discussed in Niger is the effect of recent devaluations of the naira on the cereals market.[24] We assumed that during the pre-reform period the relationship between Niger supply and demand and Nigerian price (expressed in CFA francs) was such that imports and exports were negligible in the Niger market. But devaluations of the naira have been substantial in recent years, and there is evidence that Niger now imports significant amounts of millet and sorghum from Nigeria. In terms of out supply and demand models, the cereals market in Niger may now be better represented by Figure 3c than Figure 3a. The devaluations have lowered the Nigeria price (PN) to a sufficient degree that imports now take place (indicated by the distance B"F). The price available to Niger producers is now lower than that implied by the model we used to generate our estimates. Hence output would be reduced as we move down along the demand curve. This would argue that reforms have had an even greater than measured impact, since if properly specified the model would have yielded lower predicted values (and thus higher residuals) as a result of the lower price. Unfortunately, neither the price nor trade data necessary to incorporate this factor are available.

A possible explanation to the seemingly stronger performance of sorghum in the post-drought period is that sorghum production is concentrated in the Zinder and Maradi departments along the Nigerian border, those regions accounting for over 60% of national production of sorghum as compared to just 40% of millet. It is possible that spatial variations in rainfall which our national aggregation masks, or differing trade patterns

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[23]Cited by C.A. May of the FEWS Project in a personal communication to the authors, August 8, 1990.

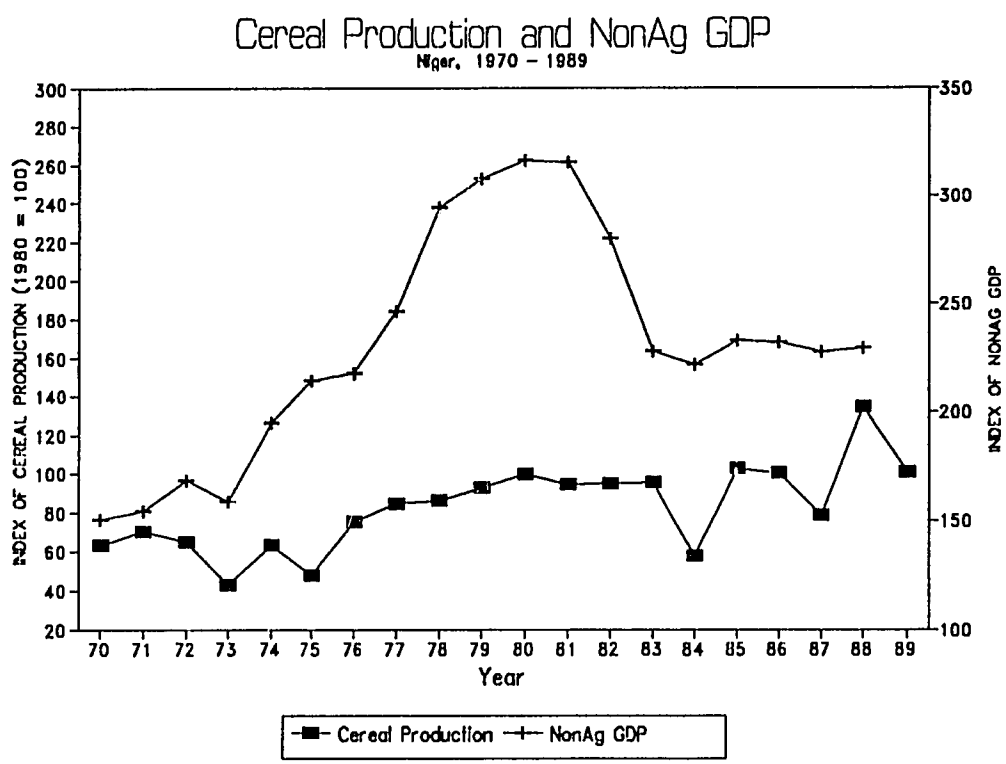
[24]Our model uses the parallel market rate for naira because that is the relevant rate for most cross-border trade. If anything, official naira devaluations follow market rate depreciation.

(especially with regard to the increased imports mentioned above) have positively influenced sorghum production relative to that of millet.

Changing the Reform Year

Interestingly, testing the hypothesis that the reforms took effect starting in 1985 yields a different set of results with the residuals for the post-reform years being significantly different from the pre-reform years. For example, in the combined millet and sorghum estimates (shown in Table 4, column d) the mean residual for post-reform years is over 600 tons, about one-third of actual output during that time. The same is true for millet alone, where all five years show positive residuals with a mean of 550 thousand tons almost forty percent of output. When estimated for sorghum, the five-year model also yields uniformly positive residuals, though not as impressive as for millet. The mean difference between actual and predicted sorghum production for the 1985-89 period is 67 thousand tons, or 16 percent of output.

Figure 4



Is it possible that reforms did really take effect almost immediately as would be supported by this evidence? Perhaps, though the qualitative

assessment of reform implementation suggests that 1985 and 1986 were not years of impressive achievement in liberalization. An alternative explanation is less supportive of the hypothesis. The period 1970-1982 was one of secular growth in real nonagricultural GDP. The impact of Niger's economic crisis can be seen by the steep decline from 1982 to 1984 and subsequent stagnation in this measure (Table 3 and Figure 4). When modeled over the period 1970-1984, the regression equation estimates a large coefficient for the variable NOAGGDP, so much so that the trend factor becomes negative. When these results are applied to the post-1984 period coinciding with substantially lower observations on NOAGGDP, the regression predicts secularly lower output, yielding the higher residuals. Though our theory would predict a negative marginal effect from the economic decline operating through reduced demand, this particular segmentation of the data may exaggerate its effect.

Cowpeas

In the case of the cowpea model, the depreciation of the naira is taken fully into account, since the Nigeria price (reflecting the exchange rate) is one of the variables generating the predictions of output. The results of the residual analysis are shown in Table 11. In all three post-reform years, cowpea output was higher than what could be predicted on the basis of Nigeria price, early rains, and the trend factor.[25] In 1989 actual output surpassed predicted by more than 50%. The mean residual for the period is 58 thousand tons (26 percent higher than predicted), an impressive though not statistically significant difference, consistent with the direct test using the reform-period dummy.

Apart from the reforms there are no other obvious factors excluded from the equation used for prediction purposes which might explain these positive residuals. The insect factor considered above would have produced a negative effect on output for 1987. Peculiarly, when the reform period is considered to include the 1985 and 1986 years (but excluding the drought years), the residual analysis changes considerably as shown here:

Year	Residual
1985	-109.5
1986	18.3
1987	-9.0
1988	1.7
1989	67.9
Mean	-6.1

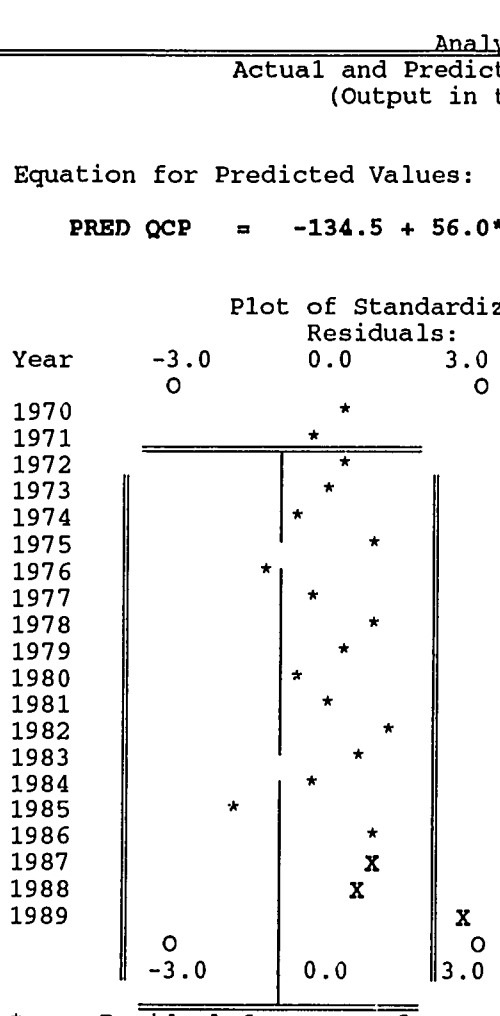
Contrary to the case for cereals, there is no evidence that reforms took hold early. This corresponds well to the implementation experience, where the monitoring of reforms suggested that as late as 1987 border officials were not aware of the liberalization of cowpea exports and considerable

[25]Other forms of the model yielded similar results.

TABLE 11
Analysis of Residuals
Actual and Predicted Cowpea Production in Niger
(Output in thousand of metric tons)

Equation for Predicted Values:

PRED QCP = -134.5 + 56.0*ERLY25 + 6.36*TREND + 0.617*PFN



Year	Actual QMS (a)	PRED QMS (b)	RESID (c)
1970	84.3	77.4	6.9
1971	72.1	78.5	-6.4
1972	144.1	125.6	18.5
1973	92.2	97.9	-5.7
1974	132.7	161.8	-29.1
1975	218.5	170.0	38.5
1976	216.1	264.7	-48.6
1977	206.8	222.6	-15.8
1978	271.5	235.7	35.8
1979	304.1	294.1	10.0
1980	266.3	295.6	-29.3
1981	275.1	275.1	-0.0
1982	271.7	217.1	54.6
1983	271.3	250.4	20.9
1984	194.8	210.3	-15.5
1985	115.3	191.6	-76.3
1986	292.9	251.4	41.5
1987	208.8	173.2	35.6
1988	301.5	274.6	26.9
1989	320.5	208.9	111.6

* = Residual for pre-reform years.
X = Residual for post-reform years.

Residuals Statistics:

Pre-reform years (1970-1986)

	Min	Max	Mean	Std Dev	N
PRED	77.44	295.58	201.75	71.95	17
RESID	-76.26	54.58	0.00	34.31	17

Post-reform years (1987-89)

PRED	173.16	274.64	218.91	51.47	3
RESID	26.86	111.56	58.02	46.57	3

obstacles to export still existed. If true that these reforms were not applied until after then, it would help explain the pattern of residuals observed in Table 11.

VII. Conclusion

Estimated models of millet, sorghum, and cowpea markets do a good job of explaining the variation in production during the pre-reform years. When these estimates are used to predict output during the post-reform years they generally under-predict, that is, actual output exceeds predicted output in most years for most crops, though differences tend not to be statistically significant. The evidence of a positive effect on output from reforms is stronger for sorghum and cowpeas than for millet. When considering that the post-reform period was characterized by some negative influences not reflected in the prediction models -- pest attacks generally and naira depreciations in the case of millet and sorghum -- the hypothesis that reforms promoted increased production and exports of cereals and cowpeas is strengthened. If the post-reform era is presumed to begin with the introduction of reforms in 1985, the models estimated for cereals suggest even more strongly that reforms had a positive effect.

Quantitative assessment of the impact of recent reforms should be an ongoing exercise as new data become available. It is quite possible that it is still too soon to permit a fair judgement about the reforms, in part because the implementation of some of them may have been delayed and also because it is reasonable to assume that the change in the behavior of producers and other economic agents that the reforms were design to influence will become more apparent over time. For statistical purposes, it will be desirable to have data on at least five post-reform years to measure statistical differences more effectively.

Several other improvements in the methodology are also suggested. Given the important role played by the price of cowpeas in Nigeria a more direct measure of this variable than our proxy based on a Nigerian food price index is desirable. We would also want to try to explicitly allow for cross-border trade in cereals in subsequent models, should data on trade and relative prices be available.[26] Though we have argued that OPVN imports are small, ideally they should be included with supply. Finally, the possibility that other environmental factors such as pest damage may improve the explanatory power of the model, the addition of such variables could eliminate additional unexplained sources of variation and help to isolate the quantitative effects of the reforms.

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[26]We did estimate the model for cereals using our Nigerian food price index under the assumption that the price of cereals, like cowpeas, are determined by the large Nigeria market. The results of these estimates show the coefficient for PFN to be insignificant. Our data, however, fail to incorporate the possibility of Nigerian imports.

TABLE A-1
Estimates of Regression Equations Using Log-linear Form
(1970-86)

Variable	(a) Combined Millet and Sorghum	(b) Millet	(c) Sorghum	(d) Cowpeas
LNLATE25	0.716 (0.473)	0.815 (0.522)	.344 (0.449)	0.269 (0.665)
LNTREND	-0.014 (0.119)	-0.018 (0.132)	0.005 (0.113)	0.244* (0.129)
LNNOAGGDP	0.726* (0.359)	0.617* (0.397)	0.791' (0.341)	
LNRAIN	-0.581 (0.738)	0.863 (0.815)	0.373 (0.670)	-0.682 (1.004)
LNERLY25	0.281 (0.375)	0.385 (0.414)	-0.063 (0.356)	1.098' (0.497)
LNPFN				0.668 (0.396)
Constant	5.749 (4.038)	7.033 (4.455)	-1.169 (3.828)	3.957 (4.281)
Cases	18	18	18	18
R^2	.593	.538	.685	.837
Adjst R^2	.407	.327	.542	.763
Deg Frdm	11	11	11	11
Durb-Wat	2.15	2.26	1.81	2.42

Numbers in parentheses below the coefiicients are standard errors.
Significance levels are indicated by:
* significant at .10 level.
' significant at .05 level.
" significant at .01 level.

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