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Aggregate Uncertainty in the Senegalese Economy

by Mark Gersovitz*
Princeton University

Preliminary: [redacted]

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1. Introduction

This paper provides evidence on various aspects of uncertainty facing the Senegalese economy. It documents the sources of uncertainty, their relative importance, their interrelationships, their indirect effects and some of the ways individual Senegalese and their government have responded to uncertainty. An important distinction is between production shocks arising from climatic variation, and international price shocks.

One important issue for policy-makers is whether these shocks can be usefully predicted so that offsetting adjustments can be made either by private sector or by the government perhaps in concert with international agencies. In the case of rainfall there does not seem to be convincing evidence that any predictions beyond a few months can be made. Whether short-run predictions are of value depends on the adjustments that can be made very quickly. International prices do, however, seem to move sluggishly so that their own past values are of use in prediction.

Even if rainfall cannot be predicted, however, it may be that the effects of past rainfall persist for more than one harvest, so that there may be scope for reaction. Arguments are discussed for these persistence effects, and evidence for them is examined.

If the impact of climatic shocks is largely confined to agriculture, then there is potential for risk-sharing between agriculture and the rest of the economy. Various channels that allow for the spillover of agricultural shocks to the non-agricultural sectors exist, however, and these are discussed. Evidence on the extent of spillover is presented.

Finally, the evidence on sources of uncertainty is brought together to suggest the scope for domestic and international risk sharing. Brief comments are made on commodity compensation schemes (STABEX, the IMF's) and on aid, foreign exchange reserves, and borrowing from private banks. This section will be expanded in a future draft of the paper.

2. Climatic Shocks

One important source of uncertainty in the Senegalese economy is year-to-year climatic variation that translates into variations in agricultural output, given the levels of inputs. In this section, I discuss some properties of climatic uncertainty. The next section discusses the link between climate and agricultural productivity.

Because the groundnut basin is so important to Senegal's agriculture, I will be focusing on the weather at Diourbel in the center of the basin. Figure 1 plots the time-series of rainfall between June and September at Diourbel. Agrometeorological sources (FAO, 1970) suggest that it may be important to distinguish between two parts of the growing season in Senegal, June to July and August to September. The amount of rainfall in the first two months will be denoted by r_1 and the second two months by r_2.

Evapotranspiration is a measure of the water balance available to crops. Agrometeorologists argue that evapotranspiration, rather than rainfall alone, is a better indicator of climatic influences on crop yields. It depends not only on rainfall, but on temperature and other variables. Linacre (1977) provides a formula for estimating evapotranspiration. I used a modified version of this formula to explain crop yields, but the results did not vary from those obtained with the rainfall variables r_1 and r_2. This outcome may be a consequence of the approximation I had to use, given limited data. This paper does not contain any analysis based on evapotranspiration because there was no advantage to it over the simpler analysis based on rainfall.

The evidence is much debated on whether current rainfall depends on the levels of rainfall in past years, i.e. the intertemporal dependence or autocorrelation of rainfall. Nicholson (1979) provides a discussion and references

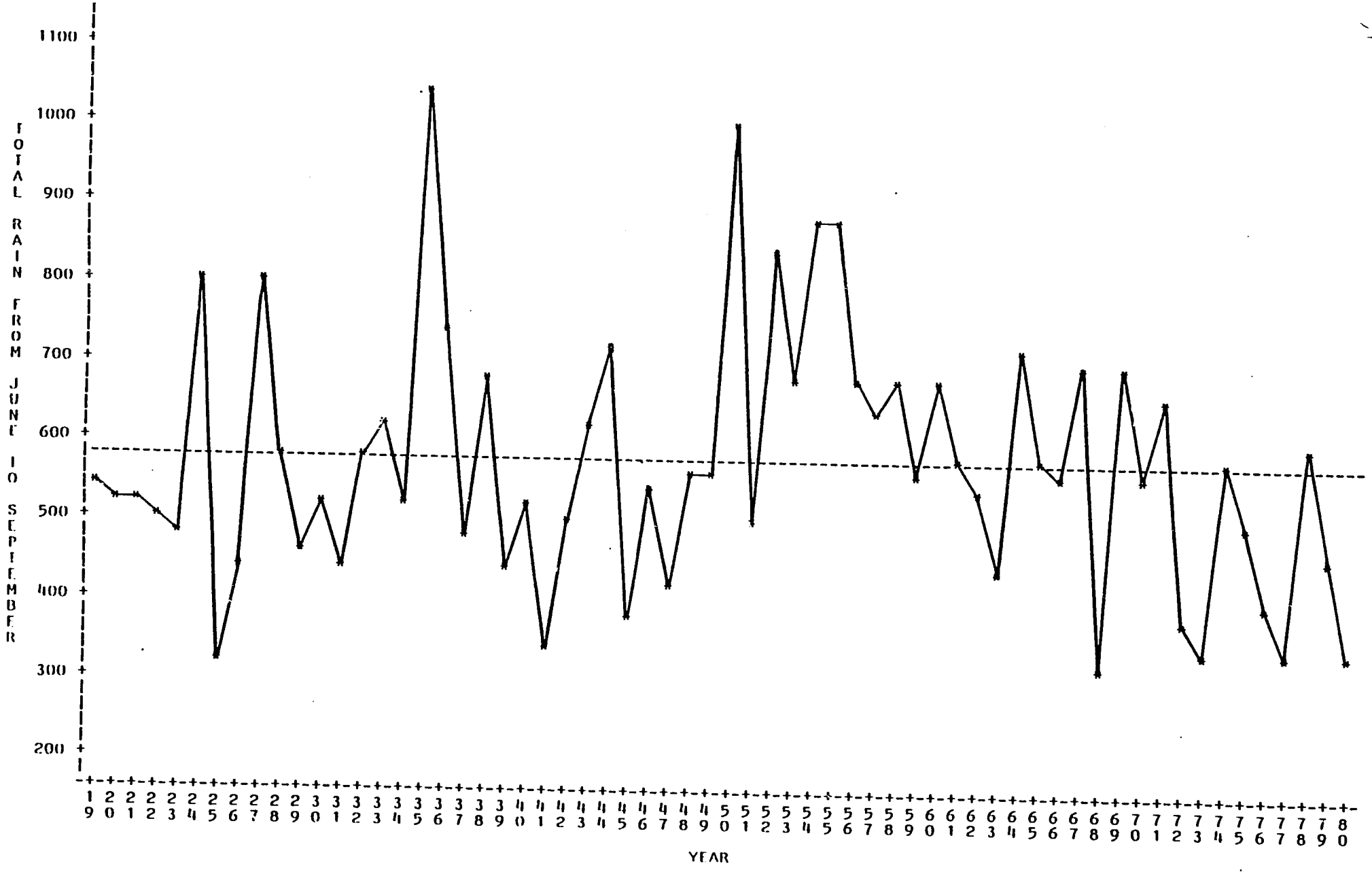

FIGURE 1
RAIN DURING THE AGRICULTURAL SEASON, MM.
SOURCE: CIEH(1976) AND DEPARTMENT OF METEOROLOGY WORKSHEETS.

on long cycles in Sahelian weather. On the one hand, if rainfall is strongly related to its past values, there is the possibility of sequences of bad years. Their cumulative effect may be worse then if they were separated by good years, as might be expected if rainfall was temporally independent. On the other hand, temporal autocorrelation means that next year's rainfall can be predicted by using the realization of this year's weather. If this is true, it may be possible to anticipate bad weather, thereby mitigating its effects.

For these reasons, it is useful to examine the relationship between current rainfall and its value in past years. Table 1 gives the regression results for r_1 and r_2 on their own values lagged one year and two years. As the first two regressions show, there is no evidence of autocorrelation in the series for r_1 and r_2. Based on these regressions rainfall appears to temporally independent; knowing last year's, or two year's ago rainfall is of no use in predicting this year's rainfall.

A related question is whether rainfall later in the growing season can be predicted from weather earlier in the year. Even if this could be done, it would be of much less use than prediction based on the rainfall of past years since the time available for acting would be much less. The third regression relates r_2 to r_1 in the same year. The coefficient of r_1 is not significant, so that this type of short-run prediction is not feasible. Some authors (Winstanley, p. 196) have suggested that weather south of Senegal early in the year can be used to predict weather during the later growing season. I have yet to investigate evidence on this issue.

A related issue is whether the southern coastal belt of West Africa tends to have good weather in years when the more northern areas, such as Senegal, have bad weather. The idea is that the Sahelian rains fail when the rain

Table 1

Rainfall Regressions

Sample Period: 1919 - 1980

Variable Definitions:

r_1: rainfall at Diourbel in June and July, millimeters

r_2: rainfall at Diourbel in August and September, millimeters

Statistics on the Variables

x	$\bar{x}$	σ	min x	max x
r_1	167	75	29	413
r_2	406	134	177	857

Where $\bar{x}$ = mean, σ = standard deviation.

Regression Results: $r_1 = \gamma_0 + \gamma_1 r_{1,-1} + \gamma_2 r_{1,-2} + u$

Coefficient	Estimate	Standard Error	t-Ratio
γ_0	$1.67 \cdot 10^2$	$3.36 \cdot 10^1$	4.95
γ_1	$-1.52 \cdot 10^{-2}$	$1.36 \cdot 10^{-1}$	0.11
γ_2	$1.52 \cdot 10^{-2}$	$1.38 \cdot 10^{-1}$	0.11

$R^2 = 0.0004$ $F_{2,58} = 0.01$

Regression Results: $r_2 = \gamma_0 + \gamma_1 r_{2,-1} + \gamma_2 r_{2,-2} + u$

Coefficient	Estimate	Standard Error	t-Ratio
γ_0	$2.94 \cdot 10^2$	$7.47 \cdot 10^1$	3.93
γ_1	$9.96 \cdot 10^{-2}$	$1.31 \cdot 10^{-1}$	0.76
γ_2	$1.79 \cdot 10^{-1}$	$1.33 \cdot 10^{-1}$	1.34

$R^2 = 0.044$ $F_{2,58} = 1.31$

Regression Results: $r_2 = \gamma_0 + \gamma_1 r_1 + u$

Coefficient	Estimate	Standard Error	t-Ratio
γ_0	$3.78 \cdot 10^2$	$4.25 \cdot 10^1$	8.88
γ_1	$1.82 \cdot 10^{-1}$	$2.33 \cdot 10^{-1}$	0.78

$R^2 = 0.01$ $F_{2,59} = 0.61$

Source of Data: CIEH (1976) and Department of Meteorology worksheets.

system does not move far enough north, but instead releases its moisture over the southern regions. This also is an issue I have yet to investigate. Its potential economic importance lies in the opportunity for risk-sharing between the Sahelian and southern states, since it suggests that their economic performance will be negatively correlated. Such a finding would have implications for institutions like the BCEAO, since it provides scope for the pooling of foreign exchange reserves among its geographically dispersed members.

Some of these same issues arise within Senegal. Table 2 presents correlation coefficients among three weather stations within the groundnut basin. Moving from south to north, these are: Kaolack, Diourbel and Linguere. Looking at the correlations within the triangle, all contemporaneous correlations of rainfall are positive, statistically significant, and moderately high. Good and bad years tend to occur together at the three places. This phenomenon is particularly marked in the comparison between Diourbel and Kaolack, suggesting that it makes sense to speak of "the" rainfall in the basin, rather than rainfall at different places. It is less so in the relationship between either of these stations and Linguere, already in a distinctly more marginal climatic zone.

In the square of Table 2 are the correlations between early rainfall and later rainfall. There does appear to be a pattern of early rainfall at stations to the south helping to predict later weather to the north as evidenced by the three correlations above the diagonal of the square. By contrast, the correlations between early weather to the north and late weather to the south are small and insignificant, as evidenced by the three correlations below the diagonal. In terms of predicting late weather from early weather at the same station (the diagonal elements of the square), only the correlation at Kaolack is significant. These results are suggestive of the value of expanded work to examine inter-African rainfall correlations along the lines suggested above.

Table 2

Spatial Correlation of Rainfall

Correlation Coefficients

		r_1		r_2		
		D	L	K	D	L
r_1:	Kaolack	0.65 **	0.43*	0.40*	0.42*	0.45*
	Diourbel		0.47**	0.06	0.13	0.44*
	Linguere			0.16	0.22	0.27
r_2:	Kaolack				0.76**	0.47**
	Diourbel					0.55**

* significant at the 0.05 level

** significant at the 0.01 level

Source of Data: As Table 1.

3. Effects of Weather on Agricultural Yields

The primary effect of weather fluctuations is on the yield of crops. While decision-makers, whether peasants or government officials, can respond to the effect of weather in past years, they can do relatively little in anticipation of what actual weather will be in any given year. This is because, as argued in the preceding section, rainfall is largely unpredictable.

This evidence leads to the view that peasants commit land and other inputs to specific crops, and then have little discretion for action after the (unpredictable) rains come. Of course, there are some decisions on inputs that affect yields but are made after the rains have fallen. For instance, effort expended harvesting the crops will depend on what the rains have been during the growing season. But if peasants harvest pretty much everything they can, the variation in this activity will only depend on the rains and not, in addition, on such factors as labor availability.

In this case, bias from omitting other factors in considering the effects of rainfall variability on yields will not be important. (In technical terminology, bias from omitted variables is zero when the omitted and included variables are uncorrelated).

Figures 2a and 2b plot the time-series of yields for the two major crops of the groundnut basin, millet and groundnuts. Table 3 presents the results of a regression analysis of the relation between various rainfall variables measured at Diourbel and the yields of these crops. This analysis will be extended to other crops in a later version of this paper, and, it is hoped to lengthen the data series as well.

The results of these regressions show that the rainfall variables are highly statistically significant. The negative coefficients on the squared terms indicate that yields are relatively more sensitive to changes in rainfall

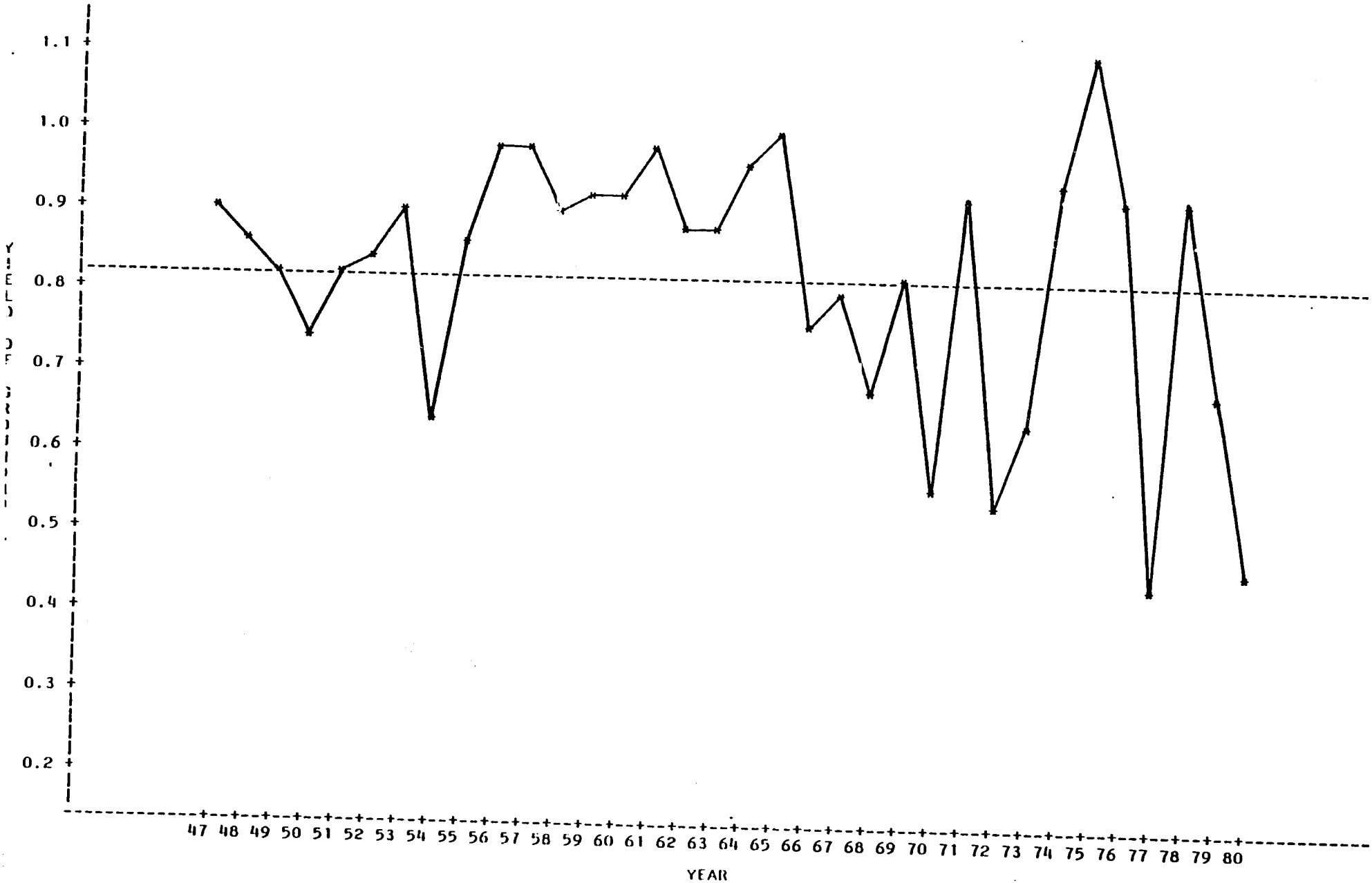

FIGURE 2A
THE YIELD OF GROUNDNUTS, TONNES PER HA.
SOURCE: DGPA WORKSHEETS AND BCEAO(NO. 19, P.2)

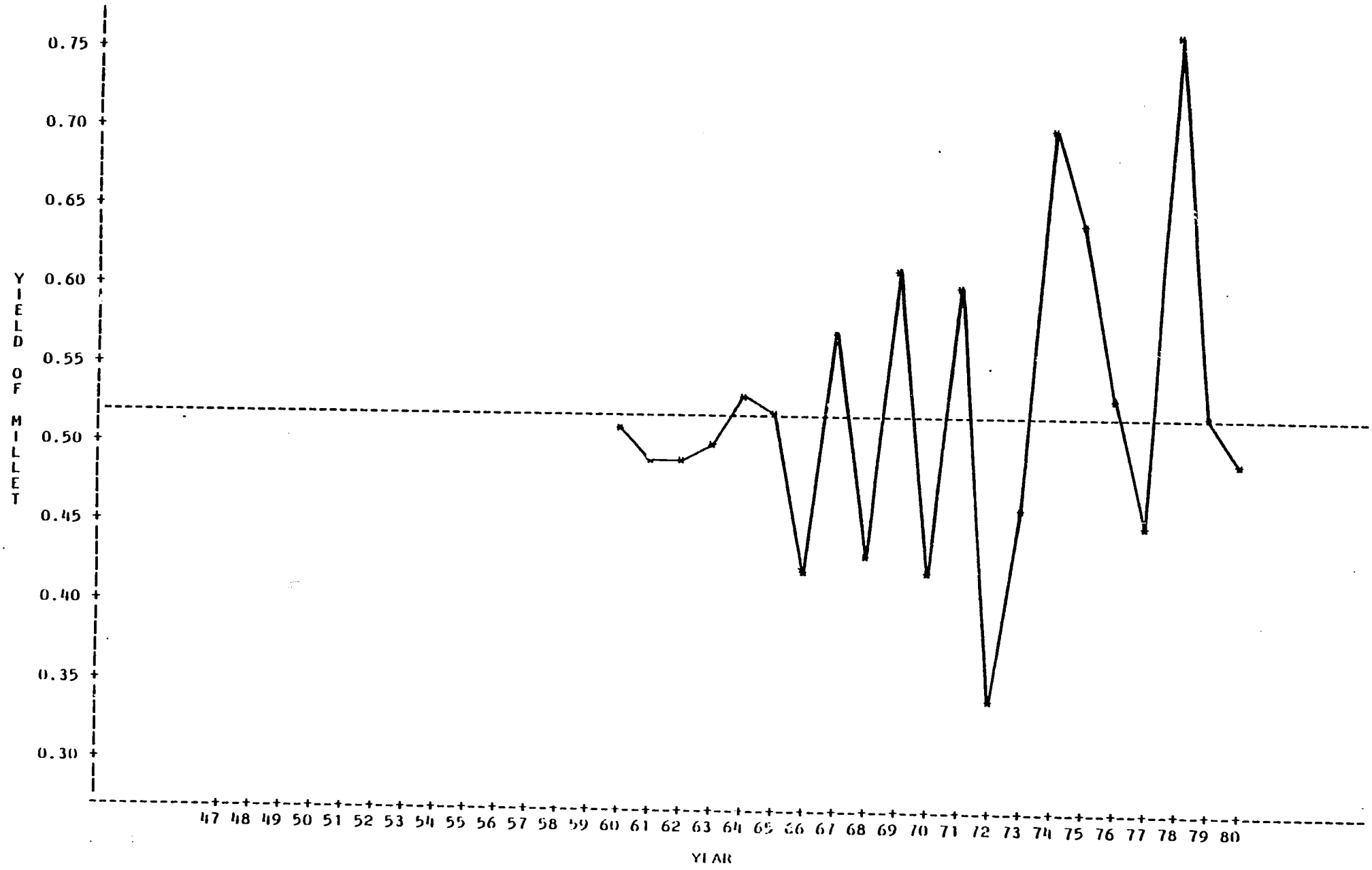

FIGURE 7B
THE YIELD OF MILLET, TONNES PER HA.
SOURCE: DGPA WORKSHEETS.

at low levels than at high levels of rainfall, as is to be expected. The trend in the yield of groundnuts is negative, but statistically insignificant and can be considered zero. The trend in the yield of millet is positive and statistically significant. The R^2's indicate that a relatively high proportion of the variation in yields can be explained by only a few rainfall variables that represent climatic conditions in a rather crude way at only one weather station in the whole groundnut area. Correspondingly, the implied role of variation in inputs (omitted largely for lack of data) must be somewhat limited.

One very important issue is the extent of the correlation between rainfall-induced variation in millet and groundnut yields, and the relative resistence of the two crops to variation in rainfall. These two aspects are conceptually distinct attributes of the two crops. For instance millet yields could be very stable, yet what little variation there was might be highly correlated with variation in groundnut yields.

To obtain evidence on these phenomena, define the rainfall related component of groundnuts and millet yields as

$$(3.1) \qquad y^r_{Gi} = 2.65\cdot10^{-3} r_{1i} - 5.75\cdot10^{-6} r^2_{1i} + 2.16\cdot10^{-3} r_{1i} - 2.22\cdot10^{-6} r^2_{2i}$$

$$i = 1919\text{-}1980.$$

$$(3.2) \qquad y^r_{Mi} = 1.59\cdot10^{-3} r_{1i} - 2.22\cdot10^{-6} r^2_{1i} + 1.80\cdot10^{-3} r_{2i} - 1.77\cdot10^{6}\, r^2_{2i}$$

where the numerical values of all coefficients are from Table 3. The correlation between y^r_G and y^r_M is 0.94, so that there is very little opportunity for diversi-

Table 3

Rainfall - Yield Regressions

Time Period: 1947 - 1980 for Y_G, 1960 - 1980 for Y_M

Variable Definitions:

t : a linear trend = 47 in 1947

y_G : yield of groundnuts, tonnes per ha.

y_M : yield of millet, tonnes per ha.
See also Table 1.

Statistics on the Variables:

x	$\bar{x}$	σ	min x	max x
y_G	0.82	0.16	0.44	1.09
y_M	0.52	0.10	0.34	0.76

Regression Results: $y_G = \gamma_0 + \gamma_1 t + \gamma_2 r_1 + \gamma_3 r_1^2 + \gamma_4 r_2 + \gamma_5 r_2^2 + u$

Coefficient	Estimate	Standard Error	t-Ratio	Joint $F_{2,28}$
γ_0	6.25	5.45	1.15	
γ_1	$-3.13 \cdot 10^{-3}$	$2.74 \cdot 10^{-3}$	1.14	
γ_2	$2.65 \cdot 10^{-3}$	$1.21 \cdot 10^{-2}$	2.19	3.36
γ_3	$-5.75 \cdot 10^{-6}$	$3.28 \cdot 10^{-6}$	1.75	
γ_4	$2.16 \cdot 10^{-3}$	$6.89 \cdot 10^{-4}$	3.13	5.37
γ_5	$-2.22 \cdot 10^{-6}$	$6.77 \cdot 10^{-7}$	3.27	

$R^2 = 0.46$ $F_{5,28} = 4.71$

Regression Results: $y_M = \gamma_0 + \gamma_1 t + \gamma_2 r_1 + \gamma_3 r_1^2 + \gamma_4 r_2 + \gamma_5 r_2^2 + u$

Coefficient	Estimate	Standard Error	t-Ratio	Joint $F_{2,14}$
γ_0	$-7.67 \cdot 10^{-1}$	$2.91 \cdot 10^{-1}$	2.45	
γ_1	$9.56 \cdot 10^{-3}$	$2.93 \cdot 10^{-3}$	3.27	
γ_2	$1.59 \cdot 10^{-3}$	$8.06 \cdot 10^{-4}$	1.98	5.35
γ_3	$-2.76 \cdot 10^{-6}$	$2.23 \cdot 10^{-6}$	1.23	
γ_4	$1.80 \cdot 10^{-3}$	$9.32 \cdot 10^{-4}$	1.93	6.47
γ_5	$-1.77 \cdot 10^{-6}$	$1.28 \cdot 10^{-6}$	1.38	

$R^2 = 0.63$ $F_{5,14} = 3.99$

fication between millet and groundnuts. The ratio of the standard deviations of y_M to the mean for the yield of millet as given in Table 3 is 0.13 while the corresponding number for groundnuts is 0.10. Thus, the rainfall induced variation in groundnuts relative to its mean is less than that for millet, and in this sense, millet is the less safe crop.

Another important question is the persistence of the effects of bad weather. Are yields affected in years following bad weather? There are a number of reasons for such a relationship: subsequent yields may be affected positively by bad weather because the failure of the crops puts lower nutrient demands on the soil, in effect acting similarly to a fallowing. This is a structural effect, in that it operates given the levels of all relevant inputs under the control of peasants. Alternatively, bad weather in a preceding year may encourage peasants to work harder in the next year to recoup their losses. This is a reduced form effect, in that if the data to control for other inputs were available it would be seen to operate through increases in these other inputs. On the other hand, peasants may transfer inputs between the crops, so that while the yield on one increases, that on the other falls. For instance, it is said that, following a bad year, risk-averse peasants will transfer their efforts from groundnuts to millet to rebuild their food stocks. In this case, millet yields rise while groundnut yields may fall. Finally, it is possible that the government's reaction to past poor rainfall will be to change groundnut prices or alter the level of inputs supplied to agriculture by the parastatals.

Table 4 presents evidence on the net effect of these different influences via the parameter α which multiplies the variables representing last year's rainfall. For groundnuts, the parameters α is positive indicating that poor

Table 4

Tests of Persistence

Regression Results:

$$Y_G = \gamma_0 + \gamma_1 t + \gamma_2 r_1 + \gamma_3 r_1^2 + \gamma_4 r_2 + \gamma_5 r_2^2 + \alpha(\gamma_2 r_{1,-1} + \gamma_3 r_{1,-1}^2 + \gamma_4 r_{2,-1} + \gamma_5 r_{2,-1}^2) + u$$

Coefficient	Estimate	Standard Error	t-Ratio
γ_0	$5.66 \cdot 10^{-2}$	$3.86 \cdot 10^{-1}$	1.47
γ_1	$-2.90 \cdot 10^{-3}$	$3.04 \cdot 10^{-3}$	0.95
γ_2	$2.86 \cdot 10^{-3}$	$1.29 \cdot 10^{-3}$	2.22
γ_3	$-6.71 \cdot 10^{-6}$	$3.44 \cdot 10^{-6}$	1.95
γ_4	$2.21 \cdot 10^{-3}$	$7.00 \cdot 10^{-4}$	3.16
γ_5	$-2.29 \cdot 10^{-6}$	$6.80 \cdot 10^{-7}$	3.37
α	$2.96 \cdot 10^{-1}$	$2.58 \cdot 10^{-1}$	1.15

Total sum of squares = 23.38 Residual sum of squares = 0.44

Regression Results:

$$Y_M = \gamma_0 + \gamma_1 t + \gamma_2 r_1 + \gamma_3 r_1^2 + \gamma_4 r_2 + \gamma_5 r_2^2 + (\gamma_2 r_{1,-1} + \gamma_3 r_{1,-1}^2 + \gamma_4 r_{2,-1} + \gamma_5 r_{2,-1}^2) + u$$

Coefficient	Estimate	Standard Error	t-Ratio
γ_0	$-1.25 \cdot 10^{-1}$	$2.87 \cdot 10^{-1}$	0.44
γ_1	$6.31 \cdot 10^{-3}$	$2.42 \cdot 10^{-3}$	2.61
γ_2	$1.40 \cdot 10^{-3}$	$5.95 \cdot 10^{-4}$	2.35
γ_3	$-2.15 \cdot 10^{-6}$	$1.61 \cdot 10^{-6}$	1.34
γ_4	$1.82 \cdot 10^{-3}$	$6.82 \cdot 10^{-4}$	2.67
γ_5	$-2.00 \cdot 10^{-6}$	$9.30 \cdot 10^{-7}$	2.15
α	$-6.01 \cdot 10^{-1}$	$2.61 \cdot 10^{-1}$	2.30

Total sum of squares = 5.93 Residual sum of squares = 0.048

Time periods, variable definitions and sources: see Table 3.

rainfall in the preceding year lowers yields in the subsequent year. But the parameter is not statistically different from zero. The results for millet, however, are reversed, the parameter α is negative and significant. Thus, bad rainfall in the previous year is associated with high millet yields in the subsequent year. Of course, this analysis does not allow the different effects to be disentangled. But it suggests that the desire of peasants to rebuild their millet stocks, perhaps even at the expense of groundnut yields, is dominant. Where possible, some of the subsequent sections address this question; lack of data, however, means that precisely distinguishing the mechanisms at work is impossible.

4. Effect of Weather on Agricultural Decisions

Both the government of Senegal and individual agriculturalists may react to the actual realization of rainfall. The scope for such reactions depend very much on the time that has passed since a particular occurrence of rainfall.

As I have argued in section 1, it is very difficult to predict what rainfall will be. Such decisions as the government's on agricultural prices and the availability of fertilizer, or peasants' on the amount of land to commit to different crops must be made before the rains occur. Since rainfall cannot be predicted, these decisions are unrelated to rainfall in the year in which they are made.

These conjectures are confirmed by regressions of: the price of groundnuts relative to the price of millet, the proportion of millet plus groundnut land planted to groundnuts and the total and per ha. use of groundnut fertilizer on r_1, r_1^2, r_2 and r_2^2 and a time trend. These regressions yielded entirely insignificant results based on data for 1961-1980.

What is somewhat more surprising is that those decisions do not respond very strongly to rainfall in the preceding year. Thus, as mentioned, it is often asserted that after a bad year, peasants seek to rebuild millet stocks. A corollery of this view would be that the proportion of land in groundnuts (T_G) should be positively related to last year's rainfall, since after a bad year peasants would shift land toward millet production. But a regression of T_G on the rainfall variables produces rainfall coefficients that are only jointly significant at the 11% level. All coefficients are, however, of the sign predicted by the hypothesis on rebuilding of millet stocks, see Table 5.

The government, however, does not appear to respond at all to previous bad weather. Regressions of the supply of groundnut fertilizer (both total

Table 5

The Lagged Effect of Rainfall

Sample Period: 1961 - 1980

Variable Definitions:

ρ : ratio of the groundnut to the millet price

T_G: percentage of groundnut plus millet land under groundnuts

See Table 1 for other definitions. All rainfall variables and ρ are lagged.

Regression Results: $T_G = \gamma_0 + \gamma_1 r_{1,-1} + \gamma_2 r_{1,-1}^2 + \gamma_3 r_{2,-1} + \gamma_4 r_{2,-1}^2 + \gamma_5 \rho_{-1} + u$

Coefficient	Estimate	Standard Error	t-Ratio	$F_{4,14}$
γ_0	$3.11 \cdot 10^2$	$5.83 \cdot 10^1$	5.34	
γ_1	$3.30 \cdot 10^{-2}$	$3.25 \cdot 10^{-2}$	1.02	
γ_2	$-7.49 \cdot 10^{-5}$	$8.62 \cdot 10^{-5}$	0.87	2.30
γ_3	$6.40 \cdot 10^{-2}$	$3.66 \cdot 10^{-2}$	1.75	
γ_4	$7.44 \cdot 10^{-5}$	$5.06 \cdot 10^{-5}$	1.47	
γ_5	$4.95 \cdot 10^1$	$3.97 \cdot 10^1$	1.25	

$R^2 = 0.53$ $\qquad F_{5,14} = 3.22$

and per ha.) and the ratio of the groundnut price to the millet price produced joint significance of the rainfall variables of 0.44, 0.64 and 0.21 respectively i.e. statistically insignificant by all conventional measures. To the extent that the results have any meaning, the coefficient values indicated that the government may raise groundnut prices relative to millet prices following a good year, thereby reinforcing the peasants' own actions on land allocation. But the evidence for all these effects is extremely weak.

5. Transmission of Rainfall Shocks to Other Sectors:

The level of rainfall affects yields and therefore agricultural output directly via plant physiology. But these shocks may then be transmitted to the rest of the economy in various ways by the actions of individual Senegalese and of the government. There are four main channels by which this transmission can take place:

First, other sectors provide inputs to the agricultural sector, inputs that are demanded in relation to the actual output rather than the planned output of the sector. Transportation of the crop is a good example.

Second, other sectors use the output of the agricultural sector as an input. The most prominent examples are the groundnut mills treated in detail in an earlier paper for the project.

Third, rainfall affects the demand for harvest labor. In years of bad rainfall individuals may migrate to the cities where they seek employment in other sectors.

Fourth, there may be general demand influences of a Keynesian sort. Rainfall affects rural incomes and the demand for goods and services produced by the other sectors. If wage and prices cannot adjust rapidly, a fall in demand may cause a loss of output and unemployment in other sectors.

The first, second and fourth factors suggest that when agricultural output is low, so will be the output of other sectors. Only the third factor acts to increase the output of other sectors when agricultural output is low. The actual path of real output in the secondary and tertiary sectors are plotted in Figures 3a and 3b, based on data from Daniel (n.d.). These data are constructed so that agricultural output is attributed to the year following the rainfall that would have affected it. Thus the marked trough in both series

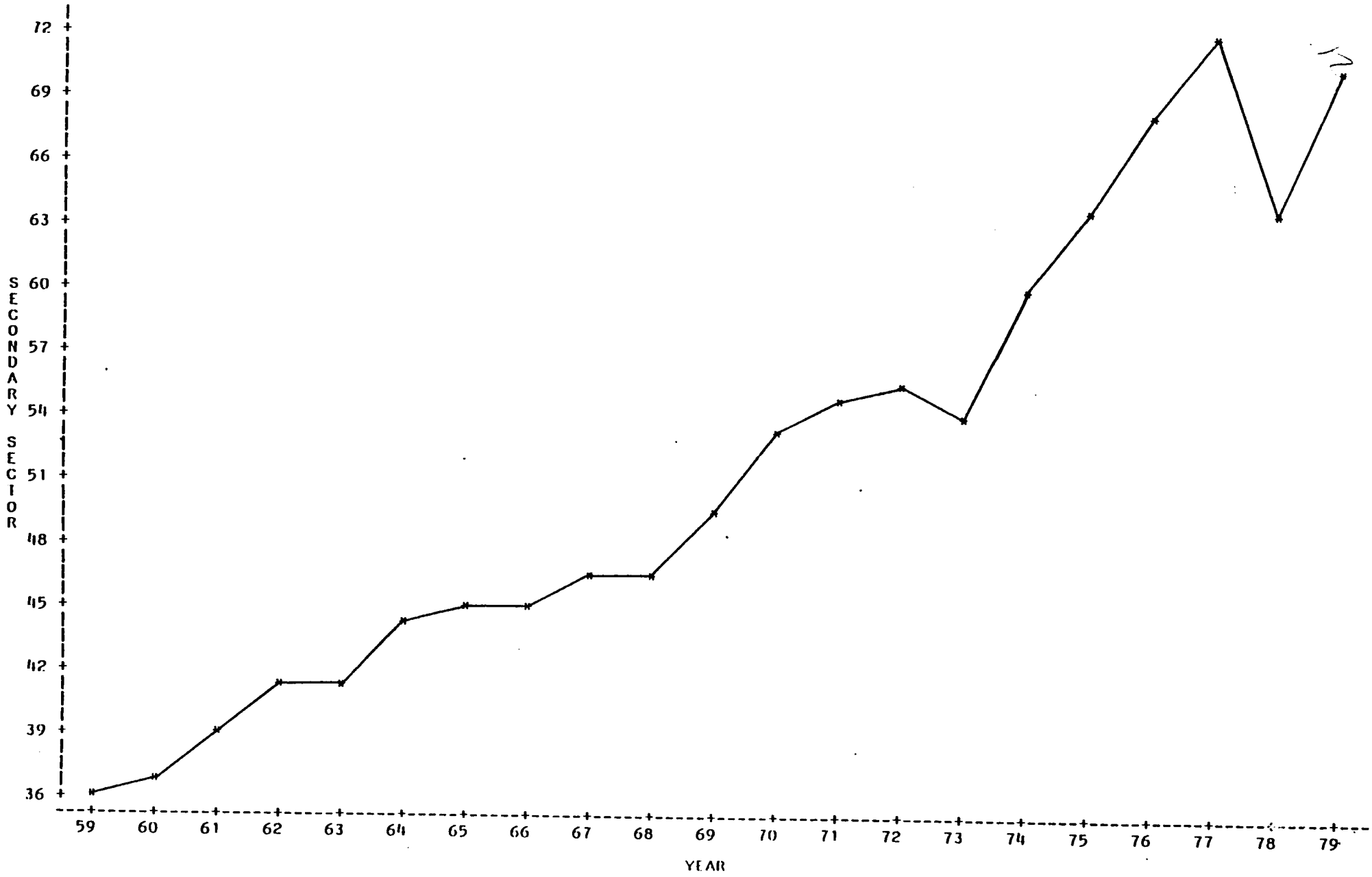

FIGURE 3A
REAL OUTPUT OF THE SECONDARY SECTOR, BNS. OF 1971 CIA
SOURCE: DANTI (N.D.)

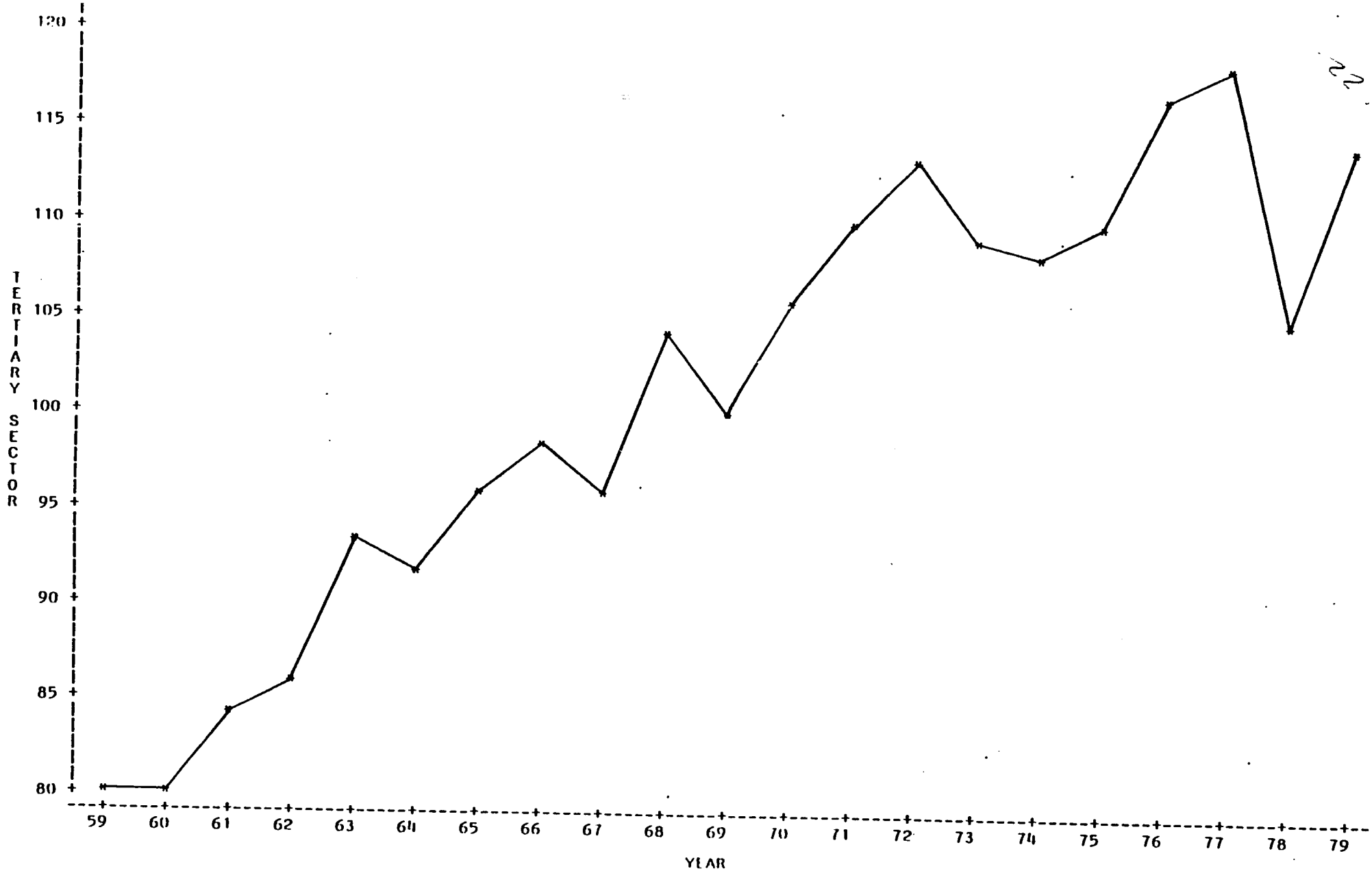

FIGURE 3B
REAL OUTPUT OF THE TERTIARY SECTOR, BNS OF 1971 CIA
SOURCE: DANIEL (N.D.)

Table 6

An Aggregated Input-Output Table for 1974

Sales by row to col.	Purchases by col. from row								
	1	2	3	4	5	6	7	8	9
1	10260	0	11638	566	1117	185	0	0	23766
2	18	5513	0	35	0	40	0	0	5606
3	0	122	20	1	0	0	0	0	143
4	160	275	0	1801	0	242	0	0	2478
5	980	3137	303	1600	13712	2114	3352	1551	26745
6	168	2036	855	865	4328	3396	2227	4270	18059
7	190	1595	2089	1337	5612	1389	1229	4414	17855
8	210	475	4399	195	1964	490	553	155	8541
9	11986	13153	19304	6400	26733	7956	7361	10390	103283
10	930	1873	684	13463	35816	2575	1018	845	57204
11	12916	15026	19988	19863	62549	10531	8379	11235	160487
12	69591	40219	45231	28518	115555	29349	26132	49908	404503
13	56675	25193	25243	8655	53006	18818	17753	38673	244016
14	320	5948	2042	4422	12982	7052	9207	9712	51685
15	0	769	864	1176	3888	2106	1859	2649	13311
16	0	754	377	726	1882	444	607	3150	7932
17	80	702	18352	2068	8959	2971	2598	16293	52023
18	56275	17789	4472	1447	29183	8351	5341	9518	132376

Definitions of Industries 1-8 (cols. & rows):

1: agriculture and husbandry

2: fishing and forestry

3: oil mills

4: other agro-industry, various food, grain and flour, sugar, tobacco, matches, confectionary

5: textiles, wood, paper, printing, chemicals, extractive industries, construction materials mechanical industries, energy, building

6: hotels, financial and misc. services

7: transportation and telecommunication

8: commerce

Definition of rows 9-18

9: sum of 1-8

10: imported inputs

11: total inputs

12: production

13: value added

14: salaries

15: expatriate salaries

16: interest and insurance

17: indirect taxes

18: sum of 13-18.

Definition of col. 9: Sum of 1-8

Source: MOP (1977).

Units: FCFA millions

in 1978 was roughly contemporaneous with the very bad rains of 1977 and similarly with 1973 (see Figure 1). Despite these two correspondences, indicating a negative relation between output in these sectors and in the agricultural sector, regressions of output in these sectors on rainfall do not produce statistically significant results. Thus regressions of secondary sector output and tertiary sector output on the four rainfall variables of Table 5 and a time trend produced joint significance of the rainfall variables of 0.53 and 0.72 respectively. Thus there is no strong statistical evidence for any transmission between agriculture and the other sectors, certainly a surprising result.

While evidence on factors three and four is especially difficult to obtain, an input-output table, given in Table 6 makes clear why the first and second factors do not operate. Most industries purchase very few inputs from agriculture, as can be seen by comparing the entries of row 1 with the entries of row 9. The only exception is industry 3, the oil mills, with large purchases from agriculture but few sales to other industries. Further, agriculture purchases relatively little of the output of the other sectors to use as inputs, as can be seen by comparing the entries of column 1 with the entries of column 9. The linkages between agriculture and the other industries is quite weak even in a year of good rainfall, 1974. The only exception is the linkage from agriculture through the oil mills which have large purchases from the service industries, 6-8.

Table 7

Measures of Expected Output

YR	A	$\hat{A}$	$\frac{A}{\hat{A}}.100$	Y	$\hat{Y}$	$\frac{Y}{\hat{Y}}.100$	$\frac{\hat{A}}{\hat{Y}}.100$	$\frac{A}{Y}.100$
60	48.3	45.1895	6.8832	198.5	195.390	1.5919	23.1279	24.3325
61	50.1	48.6856	2.9053	205.2	203.786	0.6941	23.8906	24.4152
62	49.6	50.7433	-2.2532	212.4	213.543	-0.5354	23.7625	23.3522
63	52.1	53.4397	-2.5070	218.8	220.140	-0.6086	24.2754	23.8117
64	54.3	51.3464	5.7523	226.4	223.446	1.3218	22.9793	23.9841
65	57.6	55.3339	4.0953	232.6	230.334	0.9838	24.0233	24.7635
66	54.3	56.6086	-4.0781	229.7	232.009	-0.9950	24.3993	23.6395
67	62.0	59.4763	4.2433	241.3	238.776	1.0569	24.9088	25.6942
68	54.8	60.5760	-9.5352	228.0	233.776	-2.4707	25.9120	24.0351
69	59.4	57.7517	2.8541	247.4	245.752	0.6707	23.5000	24.0097
70	51.9	49.7743	4.2708	247.3	245.174	0.8670	20.3016	20.9867
71	62.1	58.5914	5.9883	262.6	259.091	1.3542	22.6142	23.6481
72	53.8	57.1554	-5.8707	247.6	250.955	-1.3371	22.7751	21.7286
73	58.6	63.5241	-7.7515	257.0	261.924	-1.8800	24.2529	22.8016
74	72.3	69.6911	3.7435	277.2	274.591	0.9501	25.3800	26.0823
75	79.2	78.3858	1.0387	297.3	296.486	0.2746	26.4383	26.6398
76	73.5	76.0907	-3.4047	299.3	301.891	-0.8582	25.2047	24.5573
77	63.9	68.9078	-7.2674	269.2	274.208	-1.8263	25.1298	23.7370
78	80.7	77.6254	3.9608	301.9	298.825	1.0289	25.9768	26.7307

Variable Definitions:

A: Real Agricultural Output, bns. of 1971 CFA.

Y: Real GNP, bns. of 1971 CFA.

^: Designates Predicted Value of the Variable.

Source: Calculations described in the text.

6. The Evolution of Expected GNP

In this section I present some preliminary calculations on the value that GNP would have taken in each year if rainfall had been such that average yields in millet and groundnuts predicted for that year had been realized. This calculation puts the agricultural sector and its susceptibility to climatic shocks in perspective from the viewpoint of the economy as a whole. At present, I lack data on the magnitude of Senegalese groundnut processing capacity for the period when I have national accounts data. The calculations I present, therefore, do not incorporate corrections for the variation in oil production induced by weather. This is a serious shortcoming and one that will be rectified in a subsequent draft.

The expected value of output of each crop is defined using the estimated equations of Table 3. The mean of the rainfall component for each crop is defined as the average values of y^r_{Gi} and y^r_{mi} of equations (3.1) and (3.2). To these values, $\bar{y}^r_G$ and $\bar{y}^r_m$, is added $\gamma_0 + \gamma_1 t$ from Table 3 for t = 60 to 78 to generate a series of predicted yields for each year. Multiplying these yields by actual acreage and 1971 prices produces the estimated expected real value of output. These estimated values are used to form the expected value of real agricultural output and GNP in each year in 1971 prices.

Table 7 compares the actual values of these variables to their expected values as calculated in this way. As Table 7 makes clear, while weather shocks to the agricultural sector can be quite large in percentage terms, agriculture is not that large a fraction of total GNP (in an expected sense), and has been declining since independence, even correcting for weather. Thus if these shocks can be absorbed by the economy as a whole rather than by the agricultural sector alone, they are not as serious.

The results of Table 7 will be somewhat weakened by a correction for the oil mills, since rainfall shocks will then be seen to affect the non-agricultural sector as well. But given the results of the last section on

the general weakness of transmission effects, the basic conclusion of this section will probably not be undermined.

7. International Price Variability

To this point, attention has been given to the uncertainty in production coming from climatic variation. But individuals and the Senegalese government must also worry about variation in prices, most especially international prices. Policies to deal with these two types of shocks can be quite different.

At the most aggregate level, the international price variation that Senegal faces can be summarized by the terms of trade, the ratio of export to import prices. Figure 4 plots Senegal's terms of trade over the last two decades. The perspective of the entire post-independence period is valuable in underscoring that Senegal was a net gainer during the middle 1970's. Despite having no oil, Senegal benefitted sufficiently from the general commodity boon of this period that the terms of trade actually improved. Even after the second oil shock, Senegal's terms of trade were no worse than during the 1960's.

With 1975 as a base of 100, the mean value of the terms of trade was 75.6 with a standard deviation of 13.2. Thus the variation as a percentage of the mean is of the same order of magnitude as the variation in the yields of groundnut and millet.

An important issue is the covariability between the production and price shocks. If Senegal were a sufficiently large producer of any of its exports relative to the world market, then low output in Senegal would increase the price Senegal receives. The negative correlation between production and price would then act as an automatic insurance mechanism, stabilizing Senegal's income.

Table 8 presents a regression of the terms of trade on itself lagged and on the rainfall variables that have been shown to affect crop yields. The coefficients of the rainfall variables indicate that there is a positive

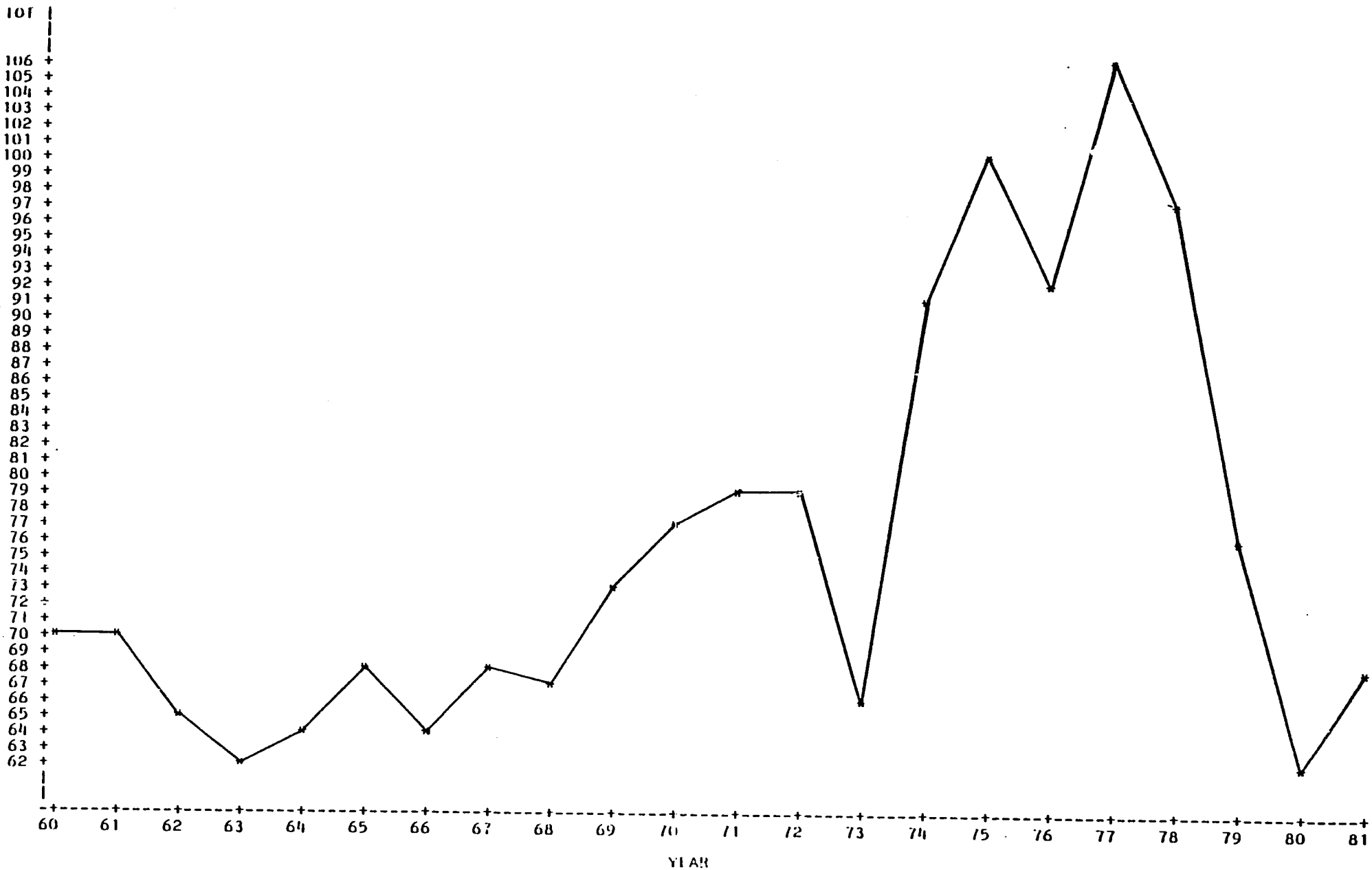

FIGURE 4
THE TERMS OF TRADE INDEX, 1975 100
SOURCE: UNCTAD(N.D.)

TABLE 8

Relation Between Rainfall and the

Terms of Trade

Sample Period: 1961 - 1980

Variable Definitions:

τ: ratio of export to import prices

See Table 1 for other definitions

Regression Results: $\tau = \gamma_0 + \gamma_1 r_1 + \gamma_2 r_1^2 + \gamma_3 r_2 + \gamma_4 r_2^2 + \gamma_5 \tau_{-1} + u$

Coefficient	Estimate	Standard Error	t-Ratio	$F_{4,14}$
γ_0	$-2.76 \cdot 10^{1}$	$2.76 \cdot 10^{1}$	1.00	
γ_1	$2.19 \cdot 10^{-1}$	$1.11 \cdot 10^{-1}$	1.96	
γ_2	$-5.68 \cdot 10^{-4}$	$3.07 \cdot 10^{-4}$	1.85	1.41
γ_3	$1.86 \cdot 10^{-1}$	$1.28 \cdot 10^{-1}$	1.45	
γ_4	$-2.46 \cdot 10^{-4}$	$1.77 \cdot 10^{-4}$	1.39	
γ_5	$7.13 \cdot 10^{-1}$	$1.85 \cdot 10^{-1}$	3.84	

Source: Terms of trade data are from UNCTAD (n.d.)

correlation between rainfall, and therefore yields, and the terms of trade, contrary to the demand-based argument. But the coefficients on rainfall are jointly significant at only the 28% level, so that the hypothesis that the terms of trade and rainfall are unrelated cannot be rejected at conventional levels of significance. Similar results were obtained in a preliminary analysis of the international price of groundnut products relative to the French consumer price index. Thus the international economy does not provide an automatic mechanism for Senegal to dissipate its production shocks via compensating changes in the terms of trade. Instead the terms of trade provide an independent, additional source of uncertainty with which the Senegalese economy must cope.

The significant coefficient on the lagged terms of trade indicates that the terms of trade can be partially predicted from its own past values. High terms of trade tend to follow high values, and vice versa. This characteristic of price shocks contrasts with the findings on rainfall.

I also undertook a preliminary correlation analysis of the relation between the domestic ratio of groundnut to millet prices and the corresponding international ratio. The correlation between the domestic ratio and either the contemporary or lagged international ratio was insignificant. Thus the government does not seem to adjust the price it sets for domestic products in response to international conditions.

8. Tentative Comments on the Extent of and Scope for Domestic and International Risk-Sharing

The empirical results of this paper are fragmentary and tentative. But a preliminary interpretation of them suggests a hierarchy with a different potential for risk-sharing at each level:

(1) There is little scope for diversification within the Groundnut Basin. Groundnuts and millet seem to respond to rainfall in much the same way.

(2) There may be more scope for risk-sharing within agriculture as a whole, since the yields on crops outside the Groundnut Basin do not seem to be related to weather at Diourbel. Further research is necessary to see if they are related to weather in the area where they are grown or if they are relatively immune to weather.

(3) The transmission of agricultural shocks to the non-agricultural sector seems to be negligible, aside from the oil mills. This suggests that there is definite scope for risk-sharing within Senegal.

(4) The international economy does not seem to provide an automatic mechanism for risk-sharing since rainfall and the terms of trade are independent rather than negatively correlated. Instead the terms of trade, which do vary significantly, are an additional source of uncertainty that Senegal faces.

(5) Although the international economy does not provide insurance through prices, it could potentially insure all of Senegal's uncertainty because the risks Senegal faces are small, and probably unrelated to the uncertainty that the rest of the world faces.

The question is then whether the potential for risk-sharing that has been identified is realized and if not, how can it be? The next draft of this paper will examine the role of STABEX, the IMF commodity compensation funds, aid, the holding of foreign exchange reserves and borrowing from private creditors as methods for dissipating the risks Senegal faces. One option that deserves special attention is insurance, based on the actual occurrence of rainfall at various weather stations. Risk-sharing between different sectors in Senegal could be achieved by the sale of tickets promising to pay various amounts depending on rainfall. Risk-sharing between Senegal and the rest of the world could be achieved in a similar fashion, by making debt repayment, STABEX or IMF payments in any year contingent on rainfall or even more directly by interesting international insurance companies in selling to the Senegalese government policies that pay various amounts depending on rainfall.