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FOOD SECURITY IN THE SAHEL: VARIABLE IMPORT LEVY, GRAIN RESERVES, AND FOREIGN EXCHANGE ASSISTANCE

John McIntire

September 1981

INTERNATIONAL FOOD POLICY RESEARCH INSTITUTE

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FOREWORD

Much of IFPRI's research focuses on the multifaceted problem of ensuring adequate food supplies to low-income people. The Institute gives major attention to direct food subsidies, employment subsidies, and employment linkages to agricultural growth as major elements of national efforts to assure food entitlements for the poor. Another aspect of the research program centers on evaluating possible international actions to mitigate the severe pressures that supply fluctuations put on the poor. IFPRI research in this area includes the following. The work of Alberto Valdés and others documents how large these fluctuations may be. Shakuntla Mehra's work shows that production variations may well increase in association with the very technologies that offer the basic solution to food scarcity. Tim Josling's work considers how actions of developed countries may exacerbate supply fluctuations and Dan Morrow's examines the role of international stocks. Alberto Valdés and Barbara Huddleston are studying possible effects of an international food facility. A joint conference with CIMMYT explored the potential for various financial mechanisms to deal with fluctuations in production and in food import bills.

In this research report John McIntire compares the ability of alternative stock and financial policies to reduce fluctuations in food availability in the Sahel. This focus is in recognition of the particularly serious food instability problems of the Sahel, the general poverty of the area, and the consequent need to search for the most efficient solution. The study finds considerable scope for saving resources so greatly needed for overall development if an appropriate financial mechanism can be established and adequately linked to national institutions. The potential cost savings over increased stocks are so great as to argue strongly for efforts to ensure effective operation of the requisite institutions and food distribution systems at national and international levels. In the meantime expensive stocks may be necessary, but one may hope that this documentation of the costs will itself generate pressures for reform.

John W. Mellor

Washington, D.C.
September 1981

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Robin Donaldson wrote the computer program for the simulation model; the author is especially grateful for her excellent work. Pat Tillman prepared data files and provided other statistical services for the study.

Charles Hanrahan of USDA originated the project and gave useful guidance at its outset. Alberto Valdés and Barbara Huddleston gave necessary support and encouragement throughout the course of the work. Peter Hazell, Ammar Siamwalla, and Cathy Jabara gave the first draft rigorous criticism; Chris Delgado provided the author the great benefit of his knowledge of the region. Staff members of the U.S. Agency for International Development received the author courteously on his trip to the Sahel in 1979.

1

SUMMARY

The confluence of droughts and high world grain prices in the late 1960s and early 1970s in the Sahel produced widespread famine, resulting in extensive suffering and displacement of people. The region is extremely poor in normal times and the drought was simply a crisis superimposed on chronic misery. The area has recovered somewhat since 1974 but has maue little real progress. There has been, in particular, little growth of real income among agricultural populations, a steep increase in food imports, a high rate of permanent rural emigration (due partly to poor economic opportunities in agriculture), and chronic inflation.

Low economic growth and unstable food consumption have received intense attention recently. There is a general recognition that the problem of growth can be solved only by fundamental measures, principally by increasing the rate of investment in physical and human capital. There is debate about the correct emphases on export and import substitution crops and on irrigated and rainfed agriculture in growth strategies, but no one denies that agriculture must be the basis of economic progress in the Sahel.

There is much less agreement about foodgrain consumption stabilization. One view, which coincides with the official view in some countries, is that security stocks are the basis of stabilization and of the advance toward regional and national food self-sufficiency. Uncertainty about production, imports, and transport is the source of this view. An opposing view is that stocks can only be a "first line of defense" and that they have essentially nothing to do with increasing the average rate of self-sufficiency. That security stocks are economically unprofitable and can damage incentives to production are the sources of the second view.

The sizes of reserves necessary to stabilize consumption are also in dispute. The so-called official view assumes that reserves should be proportional to the size of the deficit population without considering possible adjustments in consumption or imports, and without specifying the expected frequencies and terms of withdrawals from stocks. Others have attempted to estimate the frequency distributions of production shortfalls and of the underlying probability distribution of rainfall, but such estimates are open to the charge of being based on small samples, especially for grain production.

This study is intended to add some new insights to the ongoing discussion about consumption stabilization. In particular, three of the most promising policy responses for stabilizing grain consumption are evaluated in terms of their cost effectiveness and their income distribution effects. The responses analyzed are a variable levy on grain imports, grain reserves, and foreign exchange assistance. For the purposes of this report, a variable levy is a tax or subsidy put on imports to restrict domestic grain price variability to a level consistent with consumption targets. Grain reserves include only security stocks; that is, those stocks carried over from one harvest year to the next. Foreign exchange assistance is compensation for purchases of grain on the world market paid to the Sahelian countries by some international agency to help them achieve consumption stabilization. Two kinds of foreign exchange assistance are analyzed: one linked to excess food import bills, the other intended to compensate for shortfalls of net foreign exchange earnings.

The study is unique in three ways. First, it attempts to evaluate rigorously a food insurance scheme for the Sahel region. Second, it tries to identify and compare the effects of different policy responses applied jointly rather than analyzing each policy instrument in isolation. Finally, the study uses stochastic simulation as the basic methodological tool. The probabilistic approach permits confident statistical inferences which are impossible in analyses using small historical samples as projections of the high-medium-low variety.

The study covers a period of five years (1979-1983) and is conducted separately for seven countries of the Sahelian region: Chad, the Gambia, Mali, Mauritania, Niger,

Senegal, and Upper Volta. These states are members of the Comité Permanent Inter-Etats de la Lutte Contre la Sechéresse au Sahel (CILSS), although the Gambia is not part of the Sahelian ecological zone.

A simulation model is used to analyze two alternative cases. In the first case, there is no foreign exchange constraint; in the second case such a constraint exists, which means that no more than 110 percent of the trend food import bill can be spent on cereal imports. As the model is simulated for each case, any one of four market structures or constellations of demand and supply for cereals may materialize in a particular year and country. Each of these market structures has associated with it a particular policy response aimed at stabilizing consumption and at preventing owners of transport facilities from taking large rents in case of food shortages. The policy response may be a levy on grain imports, an appropriate change in security stocks, a windfall profits tax, or any combination of these three.

The simulation results allow a direct evaluation of the relative effectiveness of a variable import levy and security stocks in stabilizing food consumption. The effectiveness of foreign exchange assistance is inferred indirectly by contrasting the results of the two cases. For this purpose Case 1 is taken to represent a situation with foreign exchange assistance and Case 2 a situation with no assistance.

To check on the sensitivity of the simulation results to the assumed price elasticity of demand for cereals, all simulations are run twice, with a lower value of −0.20 and a higher value of −0.50.

Some differences exist in the results of the simulations for the coastal countries (the Gambia, Mauritania, and Senegal) and those for the interior countries (Chad, Mali, Niger, and Upper Volta). Under Case 1 (no foreign exchange constraint) the coastal countries could achieve food consumption stabilization by simply imposing a variable levy on grain imports. But if there were a foreign exchange constraint (Case 2), grain reserves of roughly 20 percent of total grain consumption could stabilize consumption in only 85 to 95 out of 100 years.

For the coastal countries, the foreign exchange constraint tends to transfer income from consumers to producers by reducing imports, thereby forcing domestic prices above import levels. As grain reserves are increased, however, domestic prices fall toward import levels so that the net effect of the foreign exchange constraint and relatively large security stocks is to provide only a small amount of protection to producers. The gross income changes—positive for producers, negative for consumers—tend to cancel, leaving a small net increase in net social benefit as the result of stabilization policies. These net benefits of security stocks are, however, much lower than the resource costs associated with grain reserves. This result holds for all levels of security storage.

In the interior countries the probabilities of stabilizing consumption are generally lower than in the coastal countries. The reason for the reduced food security in the interior countries is the occasional insufficiency of transport facilities there. Imposing a foreign exchange constraint further reduces the probability of consumption stabilization, so that it varies from 83 percent for Chad to 68 percent for Niger if there are no grain reserves but only an import levy. Security storage in the interior countries has the same general effect that it has in the coastal countries. It lowers the probability of a major consumption shortfall when there is a foreign exchange constraint on food imports, and it produces a small net social benefit that is generally less than the real resource costs of storage.

As for the relative efficiency of foreign exchange assistance in stabilizing consumption, the simulation results show that financial assistance perceptively increases consumption stability compared with the case where a foreign exchange constraint limits food imports and countries rely solely on security stocks. Similarly, at roughly equal probabilities of stability, foreign exchange assistance produces slightly greater net economic benefits than does its alternative.

To summarize the policy implications, current national security stocks, equal to about 5 percent of grain consumption, will provide acceptable levels of food security if they are well managed. There does not seem to be any need for further investments in grain reserves, if foreign exchange assistance is available. Future expansions of security storage might be justified in the interior countries where transport constraints can cause serious consumption shortfalls. One should not, however, neglect investment in transport as a longer-term alternative. It would obviously be better to alleviate transport bottlenecks by investing

in the transport sector than by investing in grain reserves.

As the comparison of security storage and foreign exchange assistance shows, monetary assistance schemes can provide more food security than grain reserves at lower costs. The IMF Food Facility is such a scheme and its implementation in the Sahel would, in association with small national security stocks, have an excellent chance of achieving food security. Foreign exchange assistance would allow recipients to purchase the qualities of grain they want; grain reserves filled with donated grain would not. Foreign exchange assistance would not necessarily increase domestic prices relative to world prices; a wider scheme of national and regional grain reserves probably would.

No policy can be effective unless several other measures are taken by the Sahel nations and by the donors. The recipients need to allocate reserve releases to the populations that need them most, principally the herders in the northern fringe of the region, who suffered the worst losses in the last drought. The recipients need also to review public policies that inhibit agricultural production, such as trade controls and uniform price policies. Though such policies are quantitatively less important than in parts of Asia or in Latin America, their existence is inconsistent with the region's publicly expressed goal of agricultural growth.

The responsibility of the donors is to reduce the uncertainty created by their policies. This could include such measures as advance payment of foreign exchange assistance or stable food aid contracts. In so doing, donor countries would relieve the Sahel countries of the burden of paying the price of that uncertainty by undertaking investments in grain reserves that would be unnecessary if foreign assistance were more reliable.

2

INTRODUCTION

Between 1968 and 1974 droughts in the Sahel caused a number of human deaths from malnutrition and related diseases, killed much of the livestock, and provoked extensive migrations of people in search of relief. This crisis occurred in one of the world's poorest regions, where the majority depend for food on rainfed agriculture of quite low productivity. Growth of production and consumption was chronically low in the 1960s and 1970s, so that the region had little capacity to respond to the shocks of poor harvests, except by further reducing already low consumption and by sacrificing livestock.[1]

Since the end of the crisis in 1974, the region has undertaken broad efforts to prevent losses from future droughts. These efforts are based on the recognition that the rate of investment in physical and human capital must be increased in order to raise productivity and incomes. It is likely that it will take many years for such investment to pay off and it is to the credit of the region's governments and aid donors that they recognize this.

It is now generally agreed that the major short-term policy concern is to stabilize agricultural production and consumption—in other words, to attain food security. This implies maintaining consumption of essential foods at an acceptable level. Long-run food security would be attained by developing agricultural and industrial productivity; short-run food security by managing supplies, including imports and food aid.

The short-run policy emphasis on achieving the goal of food security has been linked to the goal of food self-sufficiency—that is, to the objective of replacing imports with local production. Indeed, it is often said that self-sufficiency is the best guarantee of food security. When policies are announced in the Sahel they are almost invariably described as bringing the goal of food self-sufficiency a little closer. The belief that food self-sufficiency can improve food security is based on the argument that the Sahel, as a poor region, is particularly susceptible to fluctuations in international trade and that such susceptibility can be reduced by decreasing imports of food.

Although the need for long-run investments to raise agricultural productivity is seldom denied, there is more debate about these short-run policies. The debates turn mainly on the parts played by grain reserves, imports, and aid in meeting the policy objectives of food security and in preventing deprivation resulting from shortfalls in crop production. This study evaluates the economics of food security in the Sahel and analyzes the roles of each of these policy instruments.

Chapter 3 examines the sources of food instability in the region to determine how much of that insecurity is domestic and how much is imported. It also compares the insecurity of the Sahel to other regions, reviews the policies used to establish secure food supplies, and discusses the constraints imposed by the particular problems of the Sahel. Chapter 4 develops some simple models of market structures for grain production and consumption in small open economies that are used in the stochastic simulation model. Chapters 5 and 6 present the simulation model, discuss some of its operational characteristics and detail the results. The final chapter evaluates these results in terms of their policy implications.

[1] For accounts of the drought, see John C. Caldwell, *The Sahelian Drought and its Demographic Implications* (Washington, D.C.: Overseas Liaison Committee of the American Council on Education, 1975); and Jean Copans, ed., *Sécheresses et Famines au Sahel* (Paris: François Maspero, 1975).

3

THE ECONOMIES OF THE REGION

Some Basic Characteristics

The Sahelian countries are among the poorest in the world and their economic structures are typical of poor nations (see Table 1 for some summary statistics). A large share of the region's output is agricultural, and agriculture employs the majority of the labor force. Industry is unimportant, especially as an employer, and what structural change there has been since independence in 1960 in either the composition of output or of employment has occurred as a shift from agriculture to services. Very little income growth has occurred, except in Mauritania and recently in Niger, where the mining sectors have provided nearly all of the impetus.[2]

The Saharan ecological zones of Mauritania, Mali, Niger, and Chad support only nomadic grazing and are almost uninhabited. Below that zone is the Sahelian zone where economic life consists of extensive grazing of livestock and some speculative rainfed agriculture. The Savannah zone is the most densely populated and cultivated, and some pockets of rural prosperity exist in the Groundnut Basin in Senegal and in the cotton zone of southern Mali. The wettest and southernmost zones of the region, especially in Mali and Upper Volta, are actually less densely populated and cultivated than the drier savannah because of their extensive infestation with onchocerciasis. (See Appendix 1 for an analysis of rainfall data for the Sahel.)

Apart from the locations of populations, these countries have some common demographic tendencies. Since World War I all have experienced a fairly high rate of population growth, owing to a decrease in the death rate with no corresponding decrease in the birth rate. As Table 1 shows, growth rates have been at least 2 percent per annum in every country and total populations have increased about 40 percent since independence. Urban areas have grown even faster than total population growth, a tendency that accelerated in the 1970s. Seasonal migration is common, whether to the cities or to foreign countries.[3]

Regional agriculture depends on the manual cultivation of millet, sorghum, and groundnuts during a single (summer) rainy season. The amount of irrigated agriculture is trivial, except in central Mali, and tropical tree crops are almost entirely absent. Local legumes, such as cowpeas and voandzou, are important in parts of Mali, Niger, and Upper Volta. Root crops, such as manioc and yams, and cereals, such as fonio and maize, are of little importance.

Exports consist largely of cotton and groundnuts. Only Niger (uranium), Mauritania (iron ore), and Senegal (phosphate) derive significant portions of exports from industry or mining, and all but the Gambia depend on unrequited private and public transfers for much of their foreign earnings. The potential for livestock and fish exports is great, but it was severely damaged during the drought and has only recently recovered.

Government expenditures are generally a large share of the gross national products (GNP) of these countries. Most expenditures go for purchases of goods and services and for official salaries. Investment expenditures, whether as shares of GNP or of the total budget, are small, as are public subsidies and transfers. Government revenues depend mainly on import taxes, except in Niger and Mauritania, where revenue is derived from mineral production and in Mali where revenue comes from livestock taxation (See Table 2).

The region's economies, with the excep-

[2] Important among scholarly writings on the Sahel are: Eliot Berg, *The Recent Economic Evolution of the Sahel* (Ann Arbor, Mich.: University of Michigan, Center for Research on Economic Development [CRED], 1975); Comité Permanent Inter-Etats de la Lutte Contre la Sécheresse au Sahel (CILSS) and the Club of the Sahel, *Marketing, Price Policy and Storage of Food Grains in the Sahel*, 2 vols. (Ann Arbor, Mich.: CRED, 1977); and Caldwell, *The Sahelian Drought*.

[3] Food and Agriculture Organization of the United Nations (FAO), *Etude Prospective pour le Développement Agricole des Pays de la Zone Sahélienne 1975-1990*, 3 vols. (Rome: FAO, 1976), p. 59.

Table 1—Comparative indicators of population, income, and agriculture in seven Sahelian countries, 1976

	Chad	Gambia	Mali	Mauritania	Niger	Senegal	Upper Volta
Population							
Total (thousands)[a]	4,100	500	6,239[b]	1,400	5,067[c]	5,100	6,200
Urban (percent of total)[a]	13.9	14.0	13.4	23.1	9.4	38.8	12.0
Capital city (percent of urban)[d]	34.0	...	34.6	75.0	28.4	49.0	34.0
Urban growth rate (percent/year)[d]	6.3	...	4.6	5.0	5.4	4.1	5.2
Total growth rate (percent/year)[a]	2.0	2.3	2.2	2.6	2.7	2.7	2.2
Income							
GNP capita (U.S. $)	120	180	100	340	160	390	110
Agriculture (percent of GNP)	52	...	38	35	47	28	34
Industry (percent of GNP)	14	...	17	37	24	24	19
Services (percent of GNP)	34	...	45	28	29	48	47
Rate of growth (annual percent)	−1.1	...	0.9	3.7	−1.1	−0.7	0.8
Agriculture							
Total area (thousands of square kilometers)[e]	1,284	11	1,240	1,031	1,267	196	274
Arable area (thousands of hectares)[e]	19,778	616	14,198	2,127	10,776	6,329	8,889
Cropped area (thousands of hectares)[f]	1,380	296	1,888	190	4,311	2,533	3,040
Irrigated (percent)	1	1	6	2	1	5	1
Cereals (percent)	70	71	81	82	74	43	73
Cotton (percent)	10	1	6	0	1	2	2
Peanuts (percent)	7	64	11	1	4	33	5
Potential irrigated area (thousands of hectares)[e]	180	120	2,040	140	160	390	190
Labor force in agriculture (percent of total)[e]	90	80	89	85	91	73	89

Notes: Total population growth rates are for 1965 to 1975; urban population growth rates are between 1970 and 1975. Total populations are for mid-1976. Income growth rates are from 1960 to 1976. The arable area does not include areas usable for livestock; the total cropped area includes area sown with cereals, pulses, and roots and tubers.

Caldwell argues that the true natural rate of population increase "might well be little over one and one-half percent, reports of higher levels being explained by more deficient administrative censuses in the earlier years and recent underestimates of mortality. That of the Northern nomads is probably not over one percent and could be lower" (John C. Caldwell, *The Sahelian Drought and Its Demographic Implications* [Washington, D.C.: Overseas Liaison Committee of the American Council on Education], pp.13-14).

[a] International Bank for Reconstruction and Development, *World Development Indicators* (Washington, D.C.: IBRD, 1978).

[b] Mali, *Recensement Général de la Population du Mali: Résultats Provisoires* (Bamako: Bureau Central du Recensement, 1977).

[c] Estimate provided to author by Nigerian authorities.

[d] International Bank for Reconstruction and Development, *Urban Growth and Economic Development in the Sahel: Demographic Projections and Operational Strategy*. Staff Working Paper No. 315 (Washington, D.C.: IBRD, 1979).

[e] Food and Agriculture Organization of the United Nations (FAO), *Etude Prospective pour le Développement Agricole del Pays de la Zone Sahélienne 1975-1990*. 3 vols. (Rome: FAO, 1976), 2:7.

[f] FAO, *FAO Production Yearbook* vol. 30 (Rome: FAO, 1977).

Table 2—Trade, finance, and public expenditures

	Chad	Gambia[a]	Mali[b]	Mauritania[c]	Niger[d]	Senegal[d]	Upper Volta[d]
Trade[e]							
Total exports (U.S. $ million, f.o.b.)	133	57	112	207	174	703	96
Merchandise (percent)	76	78	84	88	80	71	76
Unrequited transfers (U.S. $ million)	84	3	52	124	96	84	144
Private (percent)	19	48	31	(−21)	(−17)	4	33
Total imports (U.S. $ million, c.i.f.)	222	76	207	415	246	878	282
Merchandise (percent)	52	79	54	66	60	70	67
Public debt service as percent of total exports[f]	4.8	...	3.2	33.2	7.3	5.7	4.8
International reserves in months of import coverage[f]	1.3	3.3[a]	0.4	2.6	2.4	0.5	3.2
Public finance							
Total public expenditures (U.S. $ million)[g]		23.8	97.9	255.2	106.4	385.4	85.6
Capital (percent)		22.1	4.9	32.4	21.4	16.2	16.6
Goods and services (percent)		68.8	94.1	61.5	60.2	69.6	70.9
Subsidies and transfers (percent)		8.8	1.0	6.1	8.3	14.0	8.4
Sources of finance							
Export taxes (percent)		10.4	5.3	0.9	5.7	4.3	4.0
Import taxes (percent)		56.2	33.2	41.7	16.7	38.8	63.8
Other taxes (percent)		14.5	56.6	37.8	68.8	50.4	22.3

Notes: The trade figures for Chad, Gambia, Mali, and Mauritania are for 1976; for Niger, Senegal, and Upper Volta they are for 1975. The public finance figures for Gambia, Niger, and Senegal are for 1975/76; for Mali, Mauritania, and Upper Volta they are for 1976.

[a] The public finance figures are from International Monetary Fund (IMF), *International Financial Statistics: 1977 Annual Supplement—Annual Data 1952-1976* 30 (May 1977), p. 173. Financing figures are three-year averages for 1974/75 to 1976/77.

[b] The public finance figures are Malian francs (MF) converted to dollars at average rate (478.0 MF/$) shown in IMF, *International Financial Statistics*, p. 271.

[c] The public finance figures are Mauritanian Ouguiyas (MO) converted to dollars at average rate (44.96 MO/$) shown in IMF, *International Financial Statistics*, p. 275.

[d] The public finance figures are CFA francs converted to dollars at average rate (239.0 CFA/$) for 1975-76 in Niger, Senegal, and Upper Volta, shown in IMF, *International Financial Statistics*, p. 299.

[e] IMF, *International Financial Statistics* 1977

[f] International Bank for Reconstruction and Development, [illegible] *f Development Indicators* (Washington, D.C.: IBRD, 1978).

[g] Eliot Berg, *The Recent Economic Evolution of the Sahel* (Ann Arbor, Mich.: University of Michigan, Center for Research on Economic Development, 1975), Annex B, Table VI; and United Nations, Department of International Economic and Social Affairs, Statistical Office of the United Nations, *Yearbook of National Accounts Statistics*, 2 vols. (ST/ESA/STAT/SER.07), 1977.

tion of that of the Gambia, are to a large extent under government control. It is general policy for governments to maintain agencies for the purchase and export of the principal export crops: groundnuts, cotton, gum arabic, cowpeas, sesame, and shea nuts. The agencies usually sell inputs such as fertilizers and selected seed varieties to producers of the crop. This kind of agency has existed in most of the countries since independence and is in some places linked to French companies that specialize in the development of export crops.[4]

The agencies that manage export crops generally do not buy or sell cereals. The entitlement of national cereals marketing agencies is common throughout the region. These agencies hold monopolies on domestic

[4] A principal example is the Compagnie Francaise pour le Développement des Fibres et des Textiles (DFDT), which is active in Mali, Senegal, Upper Volta, and Chad.

grain marketing in name only except in Gambia. They do not play a direct role in the production of the cereals they market but do occasionally hold monopolies on cereal imports. This is true in Senegal, Mali, and Mauritania, but not in Upper Volta and Niger, which have separate agencies for rice trade. They have little control over the national markets; private trade continues to thrive though nominally banned in some countries.

Another characteristic Sahelian policy is the organization of agricultural development into regional or crop-specific projects. Such projects provide inputs, mechanical services, and technical assistance to farmers, and sometimes market the crop, especially if it is exported. They have been most successful in the development of export crops and active, though less successful, in irrigated agriculture. Development of coarse grains has made little progress under this policy.

Finally, these countries for the most part are dependent on France for budget and balance-of-payments support. Mali and the four Communauté Financière Africaine (CFA) countries (Niger, Chad, Senegal, and Upper Volta) participate in an operations account into which they pay their foreign exchange earnings and to which they submit their import bills. The French Treasury thereby guarantees the external convertibility of the CFA franc.[5] This dependence is greatest in Mali and in Chad, where that support has allowed a fixed parity in spite of enormous current-account deficits and growing public debt service. Niger, Senegal, and Mauritania are less dependent because they rely on mineral exports which were unaffected by the drought.

Trends in Staple Consumption and Production

The discussion of food security in this report concentrates on national supply variations from year to year. Lack of data made it impossible to analyze the problem for rural and urban regions within the seven countries except in a general way. For the same reason, one cannot say very much about variations within the year, except inferentially from the seasonal patterns of grain prices.

Staple food consumption is defined as the sum of production of cereals, roots and tubers, sugar, fish and livestock products, fruits and vegetables, pulses, and groundnut products, plus net imports and changes in public stocks of cereals. Trade in root crops, private international trade in cereals, and changes in stocks of root crops have not been included in the analysis for lack of data. Changes in farm stocks of cereals have also been excluded because data are not available.

Table 3 shows that cereals make up the largest part of consumption by far in the seven countries for which data could be obtained, and that their importance has not changed since the beginning of the time series. Pulses and groundnuts are much less important than cereals, as are roots and tubers, which do not adapt well to the climate and soils of the region. In this connection it is worth mentioning, however, that agricultural statistics of roots and tubers are poorer than usual and some roots may be valuable in periods of drought. Other food groups of some significance are livestock products (Mauritania), fish (Senegal), and vegetable oils (in all countries, especially the Gambia and Senegal).

The dependence on cereals of the Sahelian countries is among the strongest in the world. Among 94 countries ranked according to the share of cereals in total calorie consumption, all of the Sahelian countries except Mauritania were in the top third.[6] This is explained by the region's natural conditions, which favor cereals over root crops, and by its poverty, which restrains the demand for highly income-elastic foods such as livestock products, fish, fruits, and vegetables.

The internal distribution of consumption is divided among three population

[5] See Holger L. Engberg, "The Operations Account System in French Speaking Africa," *Journal of Modern African Studies* 11 (No. 4, 1973): 537-545. Engberg remarks that "In principle, the French Treasury grants unlimited overdraft facilities on each operations account. . ." but qualifies the observation by noting controls placed on such overdrafts, including the interest charged on negative balances.

[6] See Alberto Valdés and Panos Konandreas, "Assessing Food Insecurity in Developing Countries," in Alberto Valdés, ed., *Food Security for Developing Countries* (Boulder, Colo.: Westview Press, 1981), pp. 25-28.

Table 3—Average consumption of important staple foods as percentage of total consumption

Country	Cereals			Pulses and Groundnuts			Roots and Tubers			Total Consumption		
	1961-65	1966-70	1971-76	1961-65	1966-70	1971-76	1961-65	1966-70	1971-76	1961-65	1966-70	1971-76
	(percent)									(calories/capita/day)		
Chad	71	72	71	20	18	17	9	10	12	1,997 (1,927)	1,896 (1,879)	1,519 (1,510)
Gambia	78	76	76	20	21	21	2	3	3	1,824 (1,824)	1,836 (1,836)	1,848 (1,848)
Mali	89	87	88	8	11	10	3	2	2	1,759 (1,759)	1,784 (1,784)	1,698 (1,698)
Mauritania	86	86	87	13	13	12	1	1	1	1,093 (987)	1,091 (976)	1,090 (976)
Niger	85	83	80	9	10	14	6	7	6	1,883 (1,792)	1,856 (1,854)	1,785 (1,782)
Senegal	76	76	77	17	16	16	7	8	4	1,782 (1,578)	1,771 (1,568)	1,752 (1,551)
Upper Volta	80	81	81	18	17	16	2	2	3	1,868 (2,018)	1,841 (1,988)	1,737 (1,876)

Source: Food and Agriculture Organization of the United Nations (FAO), "Production Yearbook Tape, 1977," Rome, 1978. (Computer printout.)

Notes: Numbers in parentheses are based on population estimates from FAO, "FAO Food Balance Sheets, 1961-65 Average to 1977," Rome, 1978. (Computer printout.) The totals are sums of cereals, roots and tubers, and pulses and groundnuts. They are close to total available calories except for Mauritania, where sugar and livestock products contribute another 25-30 percent.

groups: the sedentary agriculturalists (80-85 percent), the nomads (5 percent), and the urban population (10-15 percent). The sedentary farmers rely overwhelmingly on millet and sorghum in their diets, supplemented by vegetable oils and small amounts of meat, milk, fish, roots, tubers, and fruits and vegetables. Nomads eat livestock products, especially milk, and whatever grain they are able to purchase from the sale of labor or of animal products. City dwellers make cereals the base of their diets, but they eat much more of the two highly income-elastic cereals, rice and wheat flour. The cities of Dakar, Nouakchott, and Banjul are the source of nearly all of the national import demand for rice and wheat.[7]

Table 4 shows growth rates and variability in the production and consumption of all staple foods and of cereals between 1961 and 1977. Per capita cereal consumption fell in all countries and aggregate consumption declined in Chad. Fluctuation of aggregate consumption was among the highest in the world. Five of the countries show coefficients of consumption variation between 6 and 10 percent, with the coefficients for Senegal and Niger being much higher. In a list of 25 countries ranked according to consumption variation, Senegal and Niger ranked sixth and seventh, respectively.[8]

The origin of the general decline in consumption of staples was the decline in production, particularly in the three interior nations. None of the countries was able to maintain supplies commensurate with population growth. The poor growth rates were aggravated by one of the highest rates of supply variation in the world; among developing countries the region is exceeded in its variability of food production only by North Africa and the Middle East.[9]

Every Sahelian country has a high probability that annual cereal production will be more than 10 percent off trend.[10] Deviations of 10 percent occur at least once in every five years, and deviations of between 5 and 10 percent occur 60 percent of the time. Maximum deviations range from 20 percent (Upper Volta) to 50 percent (Mauritania).

There is, of course, no need for fluctuations in cereal production to cause consumption to vary so much. Natural conditions are such that the cropping pattern could be diversified and production variability reduced. Changes in stocks can shift consumption from low to high value periods, and international trade could be used to maintain trend consumption.

The principal opportunities to diversify crops in the region lie in expanding irrigation and in adopting a crop mix that exploits imperfect correlations across crops and zones. Irrigated agriculture is now almost nil and much of what is called irrigation is in fact risky, unproductive, and uncontrolled flooding.[11] The opportunity to diversify production by zones within the region is limited by the high correlations among the zones, as well as by the high correlations among the outputs of different crops. For example, a comparison of the coefficients of variation of production of all staples and of cereals alone (Table 4) shows that such diversification makes total staple output only slightly less variable than that of cereals alone.

Changes in stocks can also be used to maintain consumption in the face of production fluctuations. Data on public stocks just after political independence are almost nonexistent, but it is unlikely that such

[7] There is a transitional group of sedentarizing nomads who practice a kind of mixed farming. Their consumption is a blend of that of the nomadic and agricultural groups. Studies of grain consumption and demand in the Sahel include France, Secretariat d'Etat aux Affaires Etrangères, *L'Approvisionnement des Villes dans les Pays Francophones d'Afrique: Enquêtes et Perspectives*, 5 vols. (Paris: SEAE, 1972), vol. 4, *Ouagadougou*, and vol. 5, *Bamako*; Clark Ross, *Grain Demand and Consumer Preferences: Dakar, Senegal* (Ann Arbor, Mich.: CRED, 1979), and Institut Universitaire de Technologie, *Etude Budget de Consommation*, 2 vols. (Dakar: IUT, 1975).

[8] Valdés and Konandreas, "Assessing Food Insecurity."

[9] Ibid.

[10] Deviations might also be called production trend equation residuals. If $|P - \hat{P}|$ represents the absolute value of the residual, then $|P - \hat{P}| / \hat{P}$, where P is actual grain production and $\hat{P}$ is trend grain production. See U.S. National Oceanic and Atmospheric Administration and University of Missouri, Atmospheric Science Department, "Weather Crop-Yield Relationships in Drought-Prone Countries of Sub-Saharan Africa: Final Report," University of Missouri, Columbia, Missouri, 1979.

[11] See J. Dirck Stryker, Carl H. Gotsch, John McIntire, and Frederick C. Roche, "Investments in Large Scale Infrastructure: Irrigation and River Basin Management in the Sahel," U.S. Agency for International Development, Washington, D.C., 1978 (mimeographed), for a discussion of irrigation development in the region.

Table 4—Average growth rates and variability of food production and consumption, 1961-77

Country	Production				Consumption of Cereals[b]		Average Annual Growth of Population[d]
	Staples[a]		Cereals				
	Growth Rate	Coefficient of Variation[c]	Growth Rate	Coefficient of Variation	Growth Rate	Coefficient of Variation	
	(percent/year)	(percent)	(percent/year)	(percent)	(percent/year)	(percent)	
Chad	2.72	8.41	2.52	9.56	2.52	8.40	2.1
Gambia	1.23	8.23	1.00	12.69	1.78	6.63	...
Mali	0.11	12.36	0.71	13.45	0.72	9.12	2.5
Mauritania	4.62	21.49	5.22	22.91	1.22	8.18	2.6
Niger	0.23	14.70	0.43	16.19	0.04	14.33	3.0
Senegal	0.03	20.43	0.89	22.07	0.75	16.49	2.5
Upper Volta	1.34	15.56	1.25	11.79	1.52	9.80	1.6

Source: International Food Policy Research Institute, "Food Security Program," Washington, D.C., 1978. (Computer printout.)

[a] Defined as the sum of cereals, roots and tubers, sugar, fish, livestock products, fruits and vegetables, pulses, and groundnut products.

[b] Total cereals consumption, excluding international trade. Per capita consumption can be calculated by subtracting the rate of population growth from the growth rate of cereal consumption.

[c] The coefficients of variation (cv) are the standard deviations (σ) of the relative deviations from trend. For example, for consumption,

$$cv = \sigma_{(c_t - \hat{c}_t)/\hat{c}_t}$$

where c_t is actual cereal consumption in year t and $\hat{c}_t$ is trend consumption in that year.

[d] Averages of columns 2 and 3 from International Bank for Reconstruction and Development, *World Development Report 1979* (Washington, D.C.: IBRD, 1979), Table 17, p. 158.

stocks had any role in stabilization. There were isolated attempts in the French-speaking countries to invest in public storage, but they appear to have been notably unsuccessful.[12] Farm stocks were, and still are, the principal means of buffering, but they are just adequate for the farmers themselves—that is, agricultural productivity is so low that farmers cannot generate enough surplus to hold stocks for urban and nomadic consumers.

Trends in Grain Imports

Grain demand in 1961-65 was met from domestic production except in Mauritania and Senegal. Even those two nations imported only one third of the grain they consumed, whereas recorded imports were essentially zero in the interior countries.[13] By the end of the 1960s, import dependence had grown only slightly in the interior. What trade there was consisted mainly of low-quality rice (especially in Senegal) and wheat flour, with irregular trade in sorghum or maize. The slight decline in self-sufficiency in the 1960s was associated with a small shift in consumption toward wheat flour and with a miniscule decrease in average calorie intake.

During the first half of the 1970s, imports grew rapidly in Mauritania, Gambia, and Mali, due partly to low rates of production growth and partly to the effects of the drought. In all countries the growth in imports has been due to slow output growth, to urbanization, and to fluctuations in imports resulting from the drought. In spite of high rates of import growth, self-sufficiency rates are near 1.0 in the interior countries because cereal production has nearly kept pace with demand among the rural majority, as these self-sufficiency ratios for 1977 show.[14]

Chad	0.97
Gambia	0.52
Mali	0.96
Mauritania	0.26
Niger	1.00
Senegal	0.52
Upper Volta	0.96

Because of the lag between production and marketing—crops grown in one year are consumed the following year—imports should respond to production with roughly a one-year lag. Table 5 shows one-year lagged imports are significantly related to cereal production in every country but the Gambia. Unlagged imports are also related to production but less strongly in five of the

Table 5—Correlations between cereal production and imports, 1961-77

Country	Unlagged (17 observations)	One-Year Lag (16 observations)
Chad	0.0586	−0.4922[a]
Gambia	−0.7929[b]	−0.0317
Mali	−0.6478[b]	−0.7549[b]
Mauritania	−0.5708[a]	−0.5219[a]
Niger	−0.1317	−0.5868[a]
Senegal	−0.0591	−0.7317[b]
Upper Volta	0.0848	−0.6773[b]

Source: Food and Agriculture Organization of the United Nations, "Production Yearbook Tape, 1977," Rome, 1978. (Computer printout.)

[a] Significantly different from zero at the 95 percent level.

[b] Significantly different from zero at the 99 percent level.

[12] See CILSS, Club of the Sahel, and Arup Partners, *Etude sur le Stockage des Céréales dans les Pays du Sahel* 4 vols. (Paris: CILSS/Club of the Sahel, 1978); and FAO, *Evaluation Technique des Moyens de Stockage des Réserves de Grain au Sahel: Premiere Phase* (Rome: FAO, 1979) for recent evaluations of storage techniques and capacities. Both works note the existence of aged and unused facilities built before independence. The only important modern storage facilities built before 1974 were at the ports of Nouakchott, Dakar, and Banjul.

[13] In Mauritania this is due to the extremely poor conditions for agriculture. In Senegal it is the result of the historical specialization in groundnut production.

[14] Sources of data in the following text table are FAO, "Production Yearbook Tape, 1977," Rome, 1978 (computer printout); and FAO, "Trade Yearbook Tape, 1977," Rome, 1978. The self-sufficiency ratio is total cereal production divided by total cereal consumption. A country without international trade in grain would, by definition, have a ratio of 1.0.

seven countries.[15] These findings suggest that countries are following appropriate import policies and little could be gained by reallocating current cereal trade. The findings do not indicate, however, that the Sahelian countries have been able to import a sufficient amount of grains to stabilize consumption.

The role of price policy for agricultural trade balances is now recognized widely and a professional consensus is that prices in developing countries have diminished production and increased imports. Studies conducted in the Gambia, Senegal, and Mali[16] show that grain prices in the Gambia have been above world levels and have reduced imports. Malian prices, however, were probably too low in the 1960s but approached world market levels in the 1970s, so that there has been only a small negative effect on self-sufficiency. Official prices were probably subsidized in Niger and Upper Volta, thus perhaps increasing imports. In view of the ineffectiveness of official prices in most countries, the only ones that seem to have really had an effect are in Senegal and the Gambia, where imports are probably reduced by price policies.

The high variability of consumption and its declining trend for most of the Sahelian countries suggest that they are unable to import systematically to offset their low rates of production growth. To test the hypothesis that failures to maintain consumption are due to foreign exchange constraints, three indicators are investigated: the average ratio of the cereal import bill to total foreign exchange earnings, the maximum of that ratio, and the correlation coefficient between the two series. A high average implies that countries are vulnerable to foreign exchange shortfalls in average crop years. A high maximum suggests that stocks must be held for bad crop years. The correlation between the two series shows the relation between the capacity to import and the need to do so.

Table 6 demonstrates that the share of cereal imports in the value of foreign exchange earnings or in the total import bill is small in most countries. Only in Mali is it as high as 20 percent of export earnings. Senegal also has spent more than 10 percent of export earnings on food, which is fairly high compared to other developing countries. The maxima of that ratio are generally much higher than average, indicating that the region is highly vulnerable to extreme necessity arising from the inability to purchase food on international markets.[17]

It has been argued that the correlation between food import bills and export earnings, as determined by the net foreign exchange position after purchases of food imports, shows a nation's ability to maintain food consumption in view of the opportunity cost of its foreign exchange.[18] This correlation is not consistent throughout the region. Only Niger has a large negative sign, implying that its import demands are high when export earnings are low, whereas those of the Gambia, Mali, and Senegal are zero. The others show positive correlations, implying that their export earnings are above average in years of high import bills. A zero or even positive correlation between food imports and export earnings may come about just because foreign exchange is so scarce that little more can be spent in years when production shortfalls are large. The analysis of Valdés and Konandreas shows that the Sahelian countries in their sample would have received import compensation equal to roughly 10 to 100 percent of their total export earnings had a particular food security scheme been operative. Their results imply that the foreign exchange gap, the increment to be spent on the food imports necessary to maintain or nearly maintain trend consumption, was relatively large in Mali, Mauritania, and Upper Volta, but small elsewhere.

Analysis of the food import bills for the

[15] The correlations are between the residuals from estimated trend equations for total cereal production and those for total cereal imports.

[16] See the chapter on the Gambia in CILSS and Club of the Sahel, *Marketing*. Kathryn Craven and A. Hasan Tuav, "Rice Policy in Senegal" in Scott R. Pearson, ed., *Rice in West Africa: Policy and Economics* (Stanford, Cal.: Stanford University Press, 1981). John McIntire, "Rice Policy in Mali" in Pearson, ed., *Rice in West Africa*.

[17] This is taken in absolute terms and also compared to other regions of the world. For a comparison see Valdés and Konandreas, "Assessing Food Insecurity," p. 33.

[18] Ibid., p. 26.

Table 6—Food import bills: their relative significance and the causes of their variation

	Food Import Bill as Percentage of					Variation of Cereal Import Bills Due to[a]		
	Export Earnings			Total Import Bill				
	Average	Maximum	Correlation	Average	Maximum	Volume	Price	Interaction
				(percent)				
Chad (1968-77)	3.4	9.0	0.1439	2.2	6.0	90	10	−19
Gambia (1967-77)	8.9	18.6	−0.0584	7.9	13.8	83	17	−16
Mali (1967-77)	22.6	98.5	−0.0522	9.7	35.3	94	6	20
Mauritania (1968-76)	7.9	14.0	0.2674	5.7	8.3	67	33	−39
Niger (1968-75)	−3.2	14.6	−0.4540	−2.7[b]	7.1	98	2	4
Senegal (1968-76)	12.1	17.8	−0.0421	9.3	12.5	56	44	−20
Upper Volta (1968-75)	8.7	18.4	0.4643	3.6	7.5	85	15	−23

Source: International Food Policy Research Institute, "Food Security Program," Washington, D.C., 1978. (Computer printout.)

[a] The total variation of the import bill ($P \cdot Q$), where Q is the volume and P is the c.i.f. price, is decomposed into its components using the relationship

$$P \cdot Q = [\bar{P}^2 \cdot \text{var } Q \cdot P + \bar{Q}^2 \cdot \bar{P}^2 (\text{covar } P, Q)];$$

dividing by $[\bar{P}^2 \cdot \text{var } Q + \bar{Q}^2 \cdot \text{var } P]$ equals

percent var Q + percent var P + percent covar $P \cdot Q$.

[b] Niger was often a food exporter.

Sahelian countries shows that their variability is not closely related to import prices. The variance can be decomposed into three components: quantity changes, price changes, and the simple interaction between the two, which are presented in Table 6.[19] Most of the variance arises from production shortfalls; instability of import prices is important only in Senegal and Mauritania, which are the major importers. The relative weakness of the price component suggests that changes in prices of internationally traded cereals do not have a great effect on the capacity of the region to import.

In sum, the trend growth of cereal imports reflects the failure of production to keep up with population growth and, to a lesser extent, the demand shifts induced by urbanization. Import growth, in turn, has been too slow to maintain per capita consumption at a constant or growing rate, a failure due to declining, or weakly growing, real incomes. Although imports clearly had some stabilizing effect, in most countries they did not protect consumers against severe shortfalls resulting from low grain production. The inability to import the large quantities needed to maintain consumption in the drought years was the result of foreign exchange shortages, transport and port congestion, and delays in estimating the necessary quantities. Because changes in world prices were not generally responsible for the inability to import adequate supplies, international price stabilization did not make a large contribution to consumption stabilization in this region.

Policy Choices

In light of the experiences of the 1960s and 1970s, the most urgent policy problems are to increase trend consumption and to stabilize actual consumption around its trend. The first is a matter of increasing cereal production and/or exports in order to be able to import more food. Policies to raise production, whether of staple foods or of export crops, will require biologic and economic improvements in rainfed and irrigated agriculture. Those improvements are long-term ones; in the short run, it is unlikely that the region can do much more than stabilize consumption.

There are four options for stabilizing consumption—to establish security stocks, to accept food aid, to participate in a compensatory financing scheme for imports, and to manage available foreign exchange through the use of import levies so as to make imports more responsive to changes in local production. In choosing among these options, the decisive elements are the relative costs of security storage and of imports, and the extent of delays and potential uncertainties associated with the delivery of external supplies. Disregarding the latter factor, storage of local production will only be superior to imports if the sum of the local purchase price and carrying costs is less than or equal to the import price. In countries which normally import, this condition is unlikely to be met. If, however, delays in the arrival of imports raise market prices, then storage of local production has a higher expected benefit. Such delays are the strongest argument for local stocks, especially in the four interior countries.

The argument is often advanced that storage from local production can increase consumption self-sufficiency; thus storage is more favorable than imports. Under current conditions in the Sahel countries—less than 100 percent self-sufficiency, declining per capita consumption, and a rising import trend—this argument seems false. Storage from local production could raise the average level of self-sufficiency, that is, reduce the average share of imports in consumption, only by reducing average consumption. Storage of local production, therefore, even without major delays in import delivery, might only stabilize consumption at the cost of reducing it.

Because it is difficult to build up stocks from local supply when trend production is declining, there is an interest in using food aid for grain reserves. Although the exporting countries have been holding grain for food aid in reserve, an argument is current among Sahelian governments that donated grain should be held in the region because of delays in delivery. Several studies of food aid in the 1970s show that such delays were

[19] The technique used for decomposing the variability of the food import bill is described in O. R. Burt and R. M. Finley, "Statistical Analysis of Identities in Random Variables," *American Journal of Agricultural Economics* 50 (August 1968): 734-744.

significant. In some cases they were so long as to make the aid useless. Nevertheless, it is possible to reduce delays by changing approval procedures and by improving marketing structures in the recipient countries.[20]

One should add that the fundamental argument for holding reserves outside the Sahel—that they are small countries that do not affect world prices and can therefore count on the world market to hold their reserves—disappears if reserves are held in the region itself. Any benefits gained from reducing import delays by holding stocks locally need to be considered against the costs of such stocks. If it is argued that local stocks can reduce uncertainty about the availability of imports (commercial or concessional), it is possible to reply that there are other means to reduce uncertainty, including contracting forward or establishing long-run food aid agreements.

It is evident that imports will be necessary given current production trends, whether for reserves or for current consumption, and whether the reserves are held in the Sahel or in the exporting countries. The question about imports then becomes: should they be commercial or concessional? The lack of foreign exchange in several countries appears to have contributed to consumption shortfalls: in those countries further commercial imports would not be possible unless foreign exchange earnings are increased or existing earnings are reallocated from other uses. It is also apparently true that imports responded appropriately to production changes, so that reallocation of amounts currently spent on food imports would add little stability.

The choice between commercial and concessional imports depends on the relation between those import bills that can be managed commercially and those extraordinarily large bills that would require concessional assistance. For all countries in the region there will continue to be large shortfalls, requiring concessional imports. Because commercial imports will also be necessary, and because it appears that foreign exchange shortages have restricted such imports, it follows that foreign exchange assistance could improve food security in normal years and provide emergency aid in extremely bad years.

The coincidence of high world grain prices at the time of the drought ended the relatively comfortable food situation of the 1960s. Policies to prevent recurrence of the losses suffered in the drought have tended to emphasize grain reserves held in the Sahel, whether constituted from local production or from food aid. The preceding analysis suggests that production trends do not favor building up reserves from local production if imports are restricted. In fact it would generally seem to be cheaper in the first place to use imports for reserves. The analysis also suggests that foreign exchange shortages and delays in the arrival of imports (concessional or commercial) have had as much to do with consumption instability and food deficits as the lack of grain reserves. The simulation model discussed in Chapters 4 through 6 takes into account these elements of the problem—the reliability of local supply, the variability of import prices, delays in the arrival of imports, foreign exchange availability—in an attempt to find out which of the three policy instruments analyzed—a variable import levy, grain reserves, or foreign exchange assistance—is best suited, either alone or in combination with another, to improve Sahelian food security.

[20] See Christopher Stevens, *Food Aid and the Developing World* (New York: St. Martin's Press, 1979), pp. 36-39; Instituut voor Sociaal-Economische Studie van Minder Ontwikkelde Gebieden, *Study of EEC Food Aid*, vol. 1: *Characteristics, Summary, and Conclusions*, trans. Overseas Development Institute, London (Amsterdam: University of Amsterdam, 1976); CILSS, *Summary of Sahel Food Aid Request for 1978-1979*, CILSS Document No. 196-ONG (Nouakchott: CILSS, 1979), as summarized in "Sahel: le CILSS Lance un Appel d'Urgence," *Afrique Agriculture*, April 1979, 35-40; and Annik Rogier, "Distributing Food to the Sahel: A Pilot Study in Linear and Goal Programming," Pennsylvania State University, Department of Geography Paper No. 13, State College, Pa., 1975.

4

GRAIN MARKET STRUCTURES

This chapter presents several simple grain market structures typical of the Sahelian countries, emphasizing the degree of self-sufficiency and the role of transport in each of them. The market structures outlined here are defined formally in Chapter 5 as part of the simulation model developed for this study.

For a free-trade market structure without trade barriers or other price distortions and with transport and port facilities in perfectly elastic supply, the local market or c.i.f. price in any interior country y (P_y) is the sum of the c.i.f. price for coastal country x (P_x) and the transport costs from the coast to country y (k_y). Also, consumption of any Sahelian country i (C_i) exactly equals production (Q_i) and imports (M_i). Adding time subscripts t and replacing actual values by trend values as required by the set-up of the stochastic simulation model described in the next chapter, the two relationships can be expressed as:

$$\hat{P}_{yt} = \hat{P}_{xt} + k_y \text{ and} \qquad (1)$$

$$\hat{C}_{it} - \hat{Q}_{it} - \hat{M}_{it} = 0. \qquad (2)$$

Figure 1 shows the market structure associated with equations (1) and (2), omitting the subscripts for simplicity. As can be seen, in contrast to the demand curve, the supply curve is taken to be perfectly inelastic with respect to price.

Assuming that countries want to stabilize grain consumption subject to shifts in grain production (Q) and in world prices (P), different policy responses can be considered. Security stocks and an import levy are two of them. The following sections show which of these policy instruments seems most appropriate for each market structure; that is, for a particular combination of grain production and world price. The analysis is based on the assumption that P_h^* is the highest price that governments wish to defend and that P_l^* is the lowest price they wish to support. Given the demand schedule as depicted by C in Figure 2, this is equivalent to stabilizing consumption within the interval $[C_l^*, C_h^*]$. Then supply shifts from $\hat{Q}$ to Q_1 or to Q_2 as in Figure 2 would have no effect on domestic prices, if $P = \hat{P}$ and if imports are allowed to equal $C - Q$. Assuming that $Q = \hat{Q}$ and that P varies, then a variable levy can stabilize prices within the range of P_h^* to P_l^* as long as the world price is less than or equal to P_e, the market equilibrium price without any intervention. If the world price rises to P_1 then the (negative) variable levy would be paid to consumers at the rate of $(P_h^* - P_1)/P_1$ to establish the domestic price at P_h^*. Similarly, if the world price falls below P_l^* to P_2, a levy of $(P_l^* - P_2)/P_2$ would establish P_l^*.

The market structures represented in Figures 1 and 2 are fairly typical for the coastal countries, where it is unlikely that domestic supply will exceed demand within the expected range of import prices, and where the supply of port and transport facilities is probably sufficient to handle even large import demands. In those countries a variable levy is sufficient to stabilize consumption within a desired range without storage or, indeed, any other intervention. It

Figure 1 — Free trade market structure

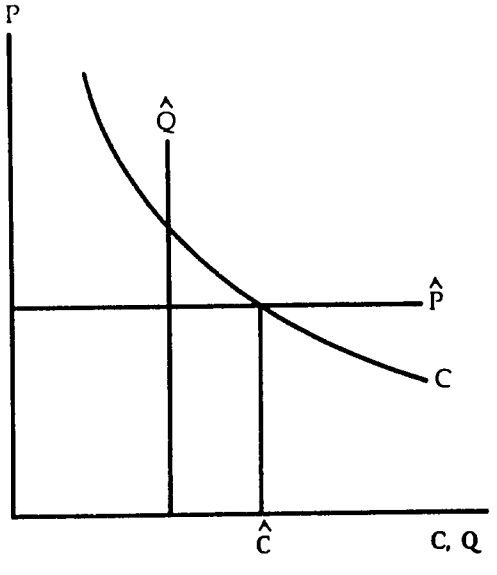
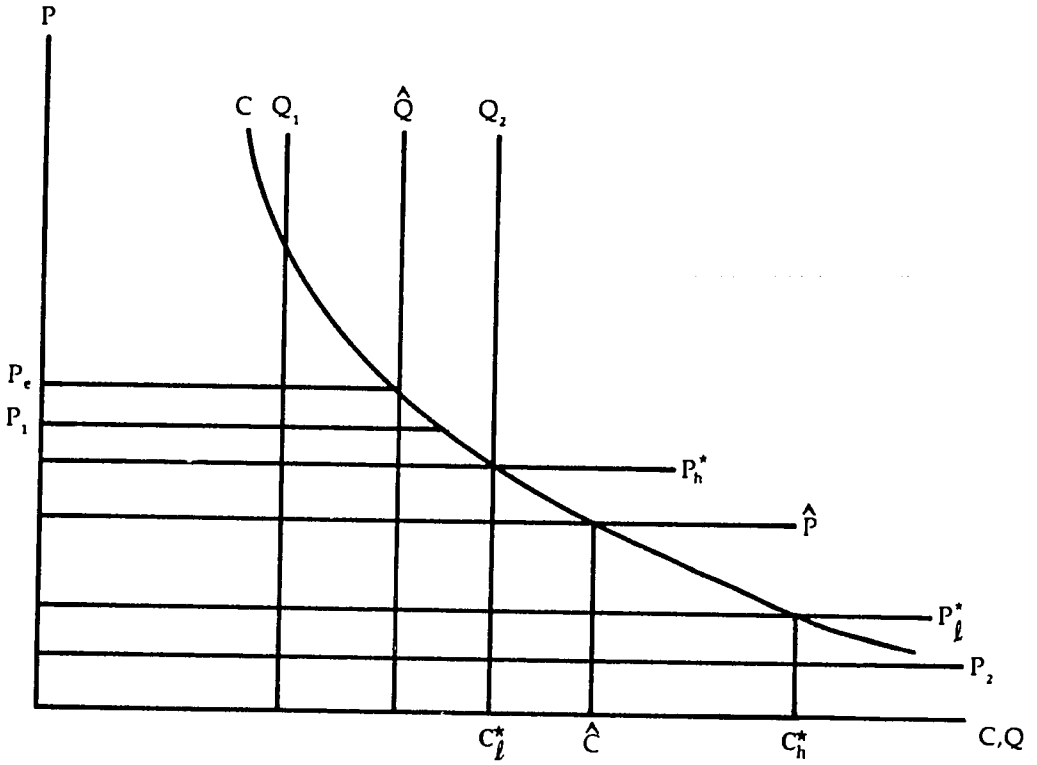


Figure 2 — Market structure with variable levy



should be noted that transport costs do not affect this conclusion, irrespective of their effect on price, as long as production is less than or equal to consumption at any price; in other words, as long as the c.i.f. price determines the domestic price before the imposition of the variable levy.

The situation for the interior countries differs from the one depicted in Figures 1 and 2 for the coastal countries. From equation (1) above we know that c.i.f. prices in the interior countries are related directly to c.i.f. prices in the coastal countries. If the interior countries are to export to the coastal countries, then the f.o.b. price in the interior countries (PX_{yt}) cannot be greater than the c.i.f. coastal price minus transport costs from interior to coast. Equation (3),

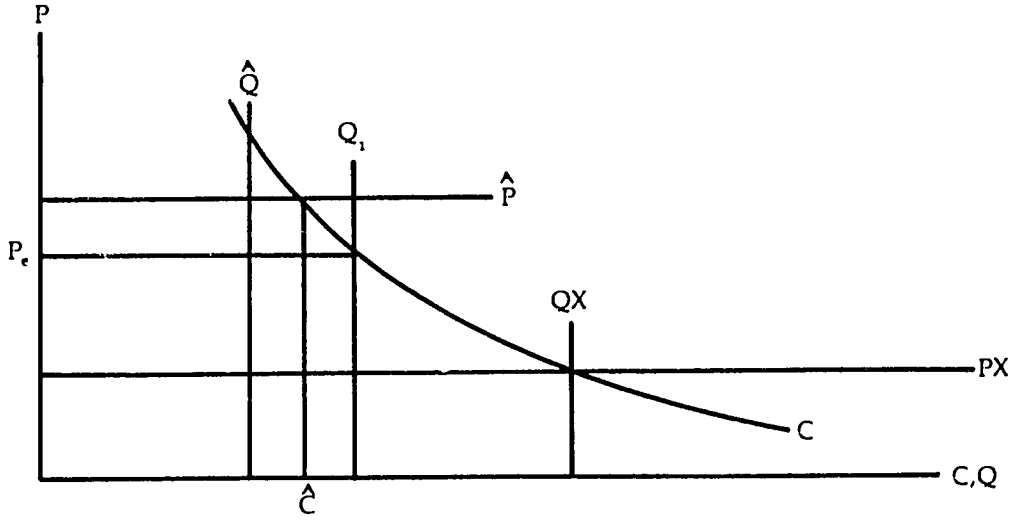
$$P_{xt} - k_y = PX_{yt}, \qquad (3)$$

expresses the competitive market's equilibrium condition. Substituting equation (1) for P_{xt} in equation (3) and ignoring hats in equation (1) for the moment gives

$$P_{yt} - (2 \cdot k_y) = PX_{yt}. \qquad (4)$$

That is, the f.o.b. price in the interior countries will be less than the c.i.f. price for any positive transport cost k_y. This relation between the f.o.b. and c.i.f. prices in the interior countries is of fundamental importance for stabilizing consumption and prices there. Also, the interior countries are different from the coastal countries because they are much closer to cereal self-sufficiency and because transport capacity may not be adequate. All these differences contribute to the fact that a variable levy will not always be sufficient to stabilize consumption for interior countries so that other policy instruments must be added. To illustrate, consider Figure 3, which depicts a market structure in which domestic grain prices are determined not by the c.i.f. price but by domestic supply and demand. Figure 3 assumes a small net importing country, producing $\hat{Q}$ and consuming $\hat{C}$ at price P. This approximates the situation in the interior countries, all of which were between 95 and

Figure 3 — Market structure in nearly self-sufficient country with quantity shifts



100 percent self-sufficient in 1977. A good harvest shifts production from $\hat{Q}$ to Q_1, whereas the c.i.f. price remains constant at $\hat{P}$. As $\hat{P}$ is the import price and not the export price, the difference between Q_1 and $\hat{C}$ cannot be exported but must be absorbed in the domestic market, causing prices there to fall to P_e, a level still far above the price level PX at which exporting will become profitable for domestic producers. In this market structure a variable levy on imports obviously has no place.

Consider now the situation in Figure 4 where production is constant at its trend value, $\hat{Q}$, but where the c.i.f. price rises from $\hat{P}$ to P. Because the c.i.f. price is again greater than the f.o.b. price— assumed to be below $\hat{P}$ as in Figure 3—the quantity $(\hat{Q} - Q_1)$ cannot be exported profitably but must be absorbed by the domestic market. The domestic price would be established where $C = \hat{Q}$, at P_e, and a variable levy would again have no effect.

The analysis so far suggests that for countries that cannot affect world prices and that import consistently, such as the coastal countries, a variable levy on imports would stabilize consumption efficiently. The levy would affect the budget of the importing agency in a positive or negative way depending on the relation of world price and domestic price. For countries, however, that shift between being importers, self-sufficient, and potential exporters, a variable levy can only stabilize consumption when these countries are actually importers. This relative instability, as compared to regular importers, is more typical of the interior Sahelian countries. It arises partly from transport costs that create a gap between the f.o.b. and the c.i.f. price and partly from the existence of transport capacity constraints, which physically limit imports. Figure 5 represents the market for transport and port services in the region. These services are assumed to be in perfectly elastic supply (S) in every country up to a capacity limit Q_1, at which point they are in perfectly inelastic supply. If the demand for such services is D_1, then their price is P_1. If the demand increases to D_2, say as the result of emergency food shipments, then price becomes P_2 and the owners of transport/port services receive an additional rent equal to the crosshatched area, that is, equal to $Q_1 \cdot (P_2 - P_1)$.

The existence of transport bottlenecks provides some justification for security storage. It also represents a special case in which a variable levy would again be ineffective in stabilizing the market. This is illustrated in Figure 6, which presents a market in which domestic production (Q) is significantly less than expected consumption ($\hat{C}$) at price $\hat{P}$. If one defines S_{MAX} as the maximum quantity that can be imported, then the sum $(Q + S_{MAX})$ determines the domestic supply, assuming no buffer stocks

Figure 4 — Market structure in self-sufficient country with price shifts

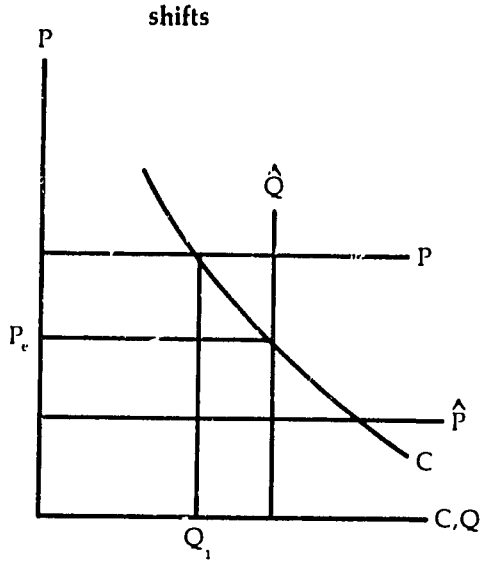


Figure 5 — Market for transport and port services

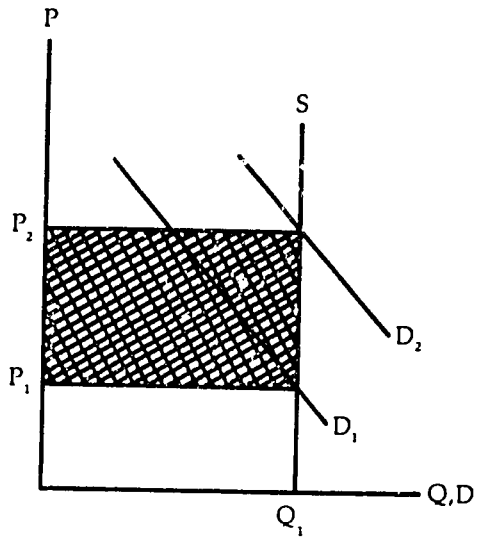
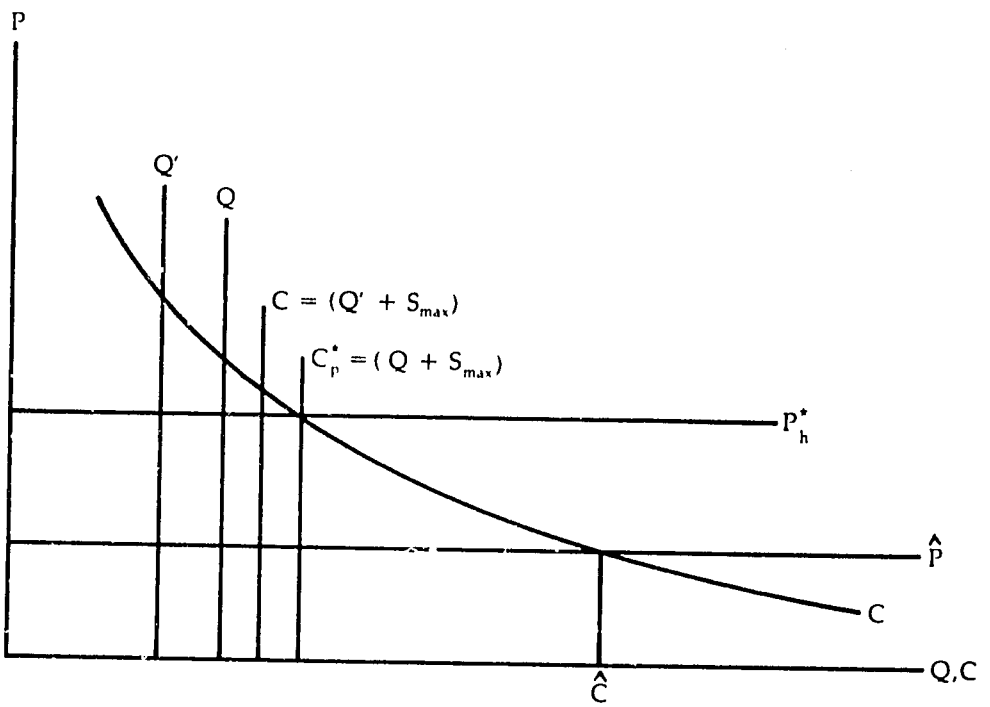


Figure 6 — Market structure with transport constraint



are in existence. If that sum is exactly equal to C_p^* (as in Figure 6), then price will be equal to P_h^*, the upper limit of what has previously been defined as the acceptable range of price fluctuations. This result obtains, however, irrespective of any variable levy on imports. A variable levy proves to be similarly ineffective in the case where domestic supply $(Q + S_{MAX})$ is less than C_p^*, say C in Figure 6. In this situation a maximum price of P_h^* can only be maintained either by quantity rationing or by drawing from buffer stocks.

To summarize, it can be seen that a variable levy can stabilize grain consumption in countries that import regularly if those countries' demands are too small to affect world prices. In countries that shift between being importers, self-sufficient, or exporters, the gap between f.o.b. and c.i.f. prices caused by transport costs makes the variable levy ineffective some of the time and necessitates other interventions. In all countries a quantity constraint for transport, port, or warehouse facilities represents a trade restriction that may render a variable levy ineffective and require other policies.

The variable levy shown here is similar in its operation to that utilized by the Senegalese rice importing agency, ONCAD, during the 1960s and 1970s. ONCAD enjoyed a rice import monopoly and sold imports at a fixed domestic price that, as it happened, was generally higher than the c.i.f. price. ONCAD's experience in stabilizing the largest Sahel grain market, in Dakar, is strong evidence that a variable levy policy could achieve consumption stabilization for the coastal countries under some conditions.[21]

That the interior countries are so close to self-sufficiency and, in some cases, so remote from world markets suggests that the principal goals of stabilization are to prevent prices from rising when there are transport constraints, and to prevent prices from falling too much when good harvests cannot be exported profitably. Neither of these problems, however, can be solved by a variable levy alone, though there will be years when a variable levy will suffice to stabilize interior markets. But on the whole it seems likely that stabilization policies in the interior countries will be more complex than in the coastal countries, where a single policy instrument, a variable levy on imports, would probably achieve stabilization objectives.

[21] See Craven and Tuluy, "Rice Policy."

5

A STOCHASTIC MODEL OF CEREAL SUPPLY, DEMAND AND TRADE

This chapter presents the model's basic equations for cereal supply, demand, and trade. On that basis, the market structures described in Chapter 4 are formally defined, together with the associated policy responses for stabilizing consumption. Finally, the respective costs and benefits of the different policy responses are discussed.

The Model's Basic Equations

Cereal Production and Consumption

Equation (5) gives expected total cereal production in each of the seven countries.

$$\hat{Q}_{it} = \hat{Q}_{io} \cdot e^{b_i(t-1961)}, \qquad (5)$$

where $\hat{Q}_{it}$ is trend cereal production in country i in year t, b_i is that country's annual growth rate of cereal production, and $\hat{Q}_{io}$ is that country's trend production in 1961. The parameters b_i were estimated by fitting logarithmic least-squares lines to FAO cereal production data for the years 1961 to 1977.

Actual grain production, Q_{it}, is given by:

$$Q_{it} = \hat{Q}_{it} \cdot (1 + q_{it}), \qquad (6)$$

where q_{it} is the relative deviation of total cereal production from its trend value. Thus,

$$q_{it} = (Q_{it} - \hat{Q}_{it})/\hat{Q}_{it}. \qquad (7)$$

The random variable q_{it} is assumed to be normally distributed[22] with an expected value of zero and a variance of σ^2. The sample variances of q_{it} (S^2_{qi}) for the years 1961 to 1977 enter a simulator which generates a population of values of q_{it}. Because the values of q_{it} among the Sahel countries are correlated (that is, covariance q_{it}, q_{jt}, is nonzero), the values of q_{it} are simulated jointly as a random multivariate based on the observed covariances for the years 1961 to 1977. It is assumed that the q_{it} are serially independent,[23] so that the covariance of q_{it} and q_{it+1} is equal to zero. It is also assumed that q_{it} is independent of world grain production or of any other factors that influence world grain prices.

Each country's total grain consumption is a function of the growth of population and of income, of the income elasticity of demand for cereals, and of the world price of wheat. Actual demand, C_{it}, is:

$$C_{it} = A_{it} \cdot P_{it}^{-n}, \qquad (8)$$

where A_{it} is the intercept of the demand curve, P_{it} is the import price of wheat, and **n** is the absolute value of the price elasticity of demand for cereals. Trend consumption, $\hat{C}_{it}$, is:

$$\hat{C}_{it} = N_{it} \cdot Y_{i1977} \cdot (1 + w \cdot g)^{t-1977}, \qquad (9)$$

where

- N_{it} = population in country i for year t;
- Y_{i1977} = per capita cereal consumption, country i, 1977;
- w = rate of real per capita income growth; and
- g = income elasticity of demand for cereals.

Note that the parameters N, w, and g are the same for every country. The relative deviation from trend consumption, c_{it}, is:

[22] The assumption that deviations of actual production from trend are normally distributed seems justified because the skewness of the production residuals for most countries studied is close to 0 and the kurtosis is close to 3.

[23] Judging from the Durbin-Watson statistic calculated from the production residuals, there is no evidence of strong temporal patterns except, perhaps for Zambia, Mali, and Upper Volta, where the statistic points to positive autocorrelation. In no case, however, is there any sign of negative autocorrelation; that is, good harvests are sequentially associated with disastrous harvests in adjacent years.

$$c_{it} = (C_{it} - \hat{C}_{it})/\hat{C}_{it}. \quad (10)$$

If c_{it} is zero, actual consumption equals trend consumption, so that the following condition,

$$A_{it} \cdot P_{it}^{-n} = N_{it} \cdot Y_{i1977} \cdot (1 + w \cdot g)^{t-1977} \quad (11)$$

holds for some value of P_{it}, since N and all the terms on the right-hand side of equation 11 are constants for any country in year t. That value of P_{it} is in fact $\overline{P}_i$, the mean price for country i, so that A_{it}, the intercept of the demand curve, has one value per year per country, and:

$$\hat{C}_{it} = A_{it} \cdot \overline{P}_i^{-n}. \quad (12)$$

The World Price of Wheat

The world market price of wheat is taken as the economic price of cereal imports and it is the price at which all grain in the model is accounted for. The mean price is based on simulated values for the coastal countries (the Gambia, Mauritania, and Senegal). The actual wheat price in the coastal countries, P_{xt}, is given by:

$$P_{xt} = \overline{P}_x + e_t, \quad (13)$$

where $\overline{P}_x$ is the mean price in the coastal countries and e_t is the random deviation from that price.[24] The mean price in the interior countries, P_{yt}, is given by:

$$P_{yt} = \overline{P}_x + k_{yx} + e_t, \quad (14)$$

where k_{yx} is transport cost to interior country y from the nearest port in coastal country x. The error term in equations (13) and (14), e_t, is independent of import demand in the Sahel, so that changes in the region's import demand have no effect on P_{xt} or on P_{yt}.

Using wheat prices requires some simplifying assumptions. One such assumption is that wheat is a perfect substitute for other grains, especially those produced in the Sahel. A second is that its use in a reserve scheme on a wider scale would not affect the value of trend cereal consumption. A third assumption is that adequate milling and storage facilities are available. In spite of these simplifying assumptions it seems nevertheless justified to base the calculations on wheat prices because wheat is the principal internationally traded foodgrain and the one most widely imported into the Sahel.

Imports

Trend cereal imports, $\hat{M}_{it}$, are equal to the difference between trend consumption and production; that is,

$$\hat{M}_{it} = \hat{C}_{it} - \hat{Q}_{it}. \quad (15)$$

Actual imports, M_{it}, are the difference between production and consumption without stock changes. Thus,

$$C_{it} - M_{it} - Q_{it} = 0. \quad (16)$$

M_{it} can be greater than, equal to, or, for an exporting country, less than zero.

The import bill is simply the quantity of food imports multiplied by the c.i.f. price. If MB_{it} represents the import bill, its trend value is:

$$\hat{MB}_{it} = \hat{M}_{it} \cdot \overline{P}_i. \quad (17)$$

Repeating the argument of Chapter 4 (equations [3] and [4]) about the effect of transport costs on the difference between c.i.f. and f.o.b. prices, earnings from cereal exports are calculated in the following man-

[24] The price generator is taken from Panos Konandreas, Barbara Huddleston, and Virabongsa Ramangkura, *Food Security: An Insurance Approach*, Research Report 4 (Washington, D.C.: International Food Policy Research Institute, 1978). It is based on a function to generate world wheat prices. In the original function, the world wheat price was related to the size of import demand in a large sample of developing countries. In the modified function used here, the world wheat price is not related to the import demand of the Sahel countries, that is, it is completely exogenous. The original price generator incorporated a first-order serial correlation into the simulated price distribution to account for stock changes in the international wheat market. This has been done here as well—again such stock changes are completely exogenous from the Sahel but they do affect the international price.

ner. Taking PX_{it} as the f.o.b. price, then:

$$PX_{it} = P_{it} - (2 \cdot k_i). \quad (18)$$

Given XB_{it} as the export earnings from cereal exports,

$$XB_{it} = |M_{it}| \cdot PX_{it}, \quad (19)$$

where M_{it} is, of course, negative.

Export Earnings

Trend foreign exchange earnings from exports of merchandise and other goods and services are derived by fitting a logarithmic least-squares regression line to International Monetary Fund (IMF) data for the period from about 1965 to 1977:

$$\hat{X}_{it} = \hat{X}_{io} \cdot e^{b_{xi}}. \quad (20)$$

The parameter b_{xi} is the annual growth rate of earnings, and $\hat{X}_{io}$ is the regression's predicted value in the base year. This value varies from one country to the next because of gaps in the data series. The actual value of foreign exchange earnings, X_{it}, is given by

$$X_{it} = \hat{X}_{it} \cdot (1 + x_{it}), \quad (21)$$

where x_{it} is a random variable with a mean of zero and variance of σ^2_{xi}. The sample observations of x_{it} are derived from

$$x_{it} = (X_{it} - \hat{X}_{it})/\hat{X}_{it}. \quad (22)$$

The sample variances S^2_{xi} enter a simulator to generate a frequency distribution of the x_{it} and those values are converted to values of X_{it} by equation (21).

Net Export Earnings

It is possible to construct a variable that gives the net foreign exchange position of a country after payment of the food import bill. This is done by subtracting the actual food import bill, MB_{it}, from the actual export earnings, X_{it}, to produce the variable NX_{it} in equation (23):

$$NX_{it} = X_{it} - MB_{it}. \quad (23)$$

The trend value of NX_{it} can be constructed in an analogous manner:

$$\hat{NX}_{it} = \hat{X}_{it} - \hat{MB}_{it}. \quad (24)$$

Market Structures and Associated Policy Responses

The study is based on the assumption that governments in each of the countries under study pursue at least two economic goals: to stabilize grain consumption so that severe consumption shortfalls are prevented in years of low production or high import prices; and to prevent economically unjustified windfall profits from food shortages.

Three policy instruments are taken to be available to governments to reach those goals: a variable levy on grain imports; changes in security stocks; and a windfall profits tax. The application of one policy instrument in isolation or in combination with any other instrument is a policy response. Different policy responses seem appropriate to different market structures, that is, to different conditions of grain demand and supply. The following section discusses how and why it can be assumed that governments in particular market structures will choose particular policy responses.

First, however, notice that foreign exchange assistance is not one of the policy instruments assumed to be available to governments. This adds a minor complication to the study as the value of this course of action can only be measured indirectly in this study. In particular, in order to identify the effectiveness of foreign exchange assistance in stabilizing consumption, the simulations are conducted for two separate cases: where a foreign exchange constraint exists and where one does not. The relative effectiveness of foreign exchange assistance is evaluated under these conditions simply by contrasting the results, where Case 1 is taken to represent a situation with foreign exchange assistance and Case 2 a situation without assistance. The foreign exchange constraint of Case 2 means that no more than 110 percent of the trend food import bill can be spent on cereal imports. Dividing the trend food-import bill by the known c.i.f. price for each year and country then generates the maximum quantity of food imports in a given year and country. Adding this constraint to the simulation

model distinguishes Case 2 from Case 1.

Turning now to the different market structures and policy responses associated with them, Figure 7 shows the basic market structure for a country that is not normally self-sufficient in cereal consumption. The country is assumed to want to stabilize its grain consumption (C) within 5 percent of trend consumption ($\hat{C}$). This band would assure that prices would be stabilized between roughly 78 and 130 percent of the mean, given the nonlinear demand curves with elasticities of −0.20. The basic objective is thus to intervene so that:

$$C^* = \hat{C}\,(1 \pm 0.05), \qquad (25)$$

where the superscript (*) indicates a stabilized value of the corresponding variable. Imposing a variable levy achieves this stabilization goal if the local market normally clears at the import price. To illustrate, if the import price rises above the maximum allowable price P^*_{mx} to for example P_2 in Figure 7 then the imposition of a negative variable levy of size $(P_2 - P^*_{mx})$ results in a loss to producers equal to area 1; areas 2, 3, and 3a are the government's financial loss, and the sum of areas 1, 2, and 3 is the consumers' gain. On the other hand, if import prices fall below the minimum acceptable price P^*_{mn} to, say, P_1, the producers' gain will be equal to area 5. Area 6 will be the government's financial gain, and the sum of areas 4, 5, and 6 will be the loss suffered by consumers.

Consider next the market structure shown in Figure 8 where effective imports of grain are constrained by port or transport capacities, a scenario that may arise when world prices and/or local production are low. Without public intervention the quantity available for consumption (Q_{mx}) would be the sum of production (Q) plus the import maximum ($Q_{mx} - Q$). The local market would clear at price P_1, a price well above the minimum acceptable price P^*_{mn} and below the maximum allowable price assumed to lie above P_1 in this scenario. The market price would in other words stabilize within the prescribed band without public intervention. The government's second economic goal, that of preventing windfall profits, would not be met, however, since the owners of transport and port services would take an increase in profits equal to the sum of areas 3 and 4 $[(Q_{mx} - Q) \cdot (P_1 - P_w)]$, where P_w

Figure 7 — Importing country without transport constraint

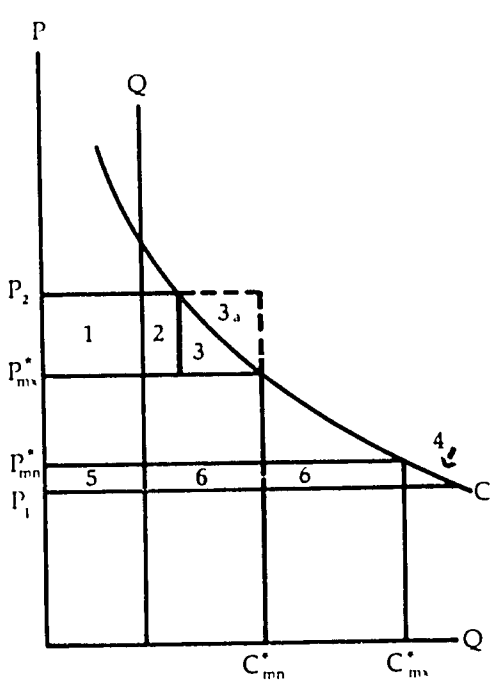
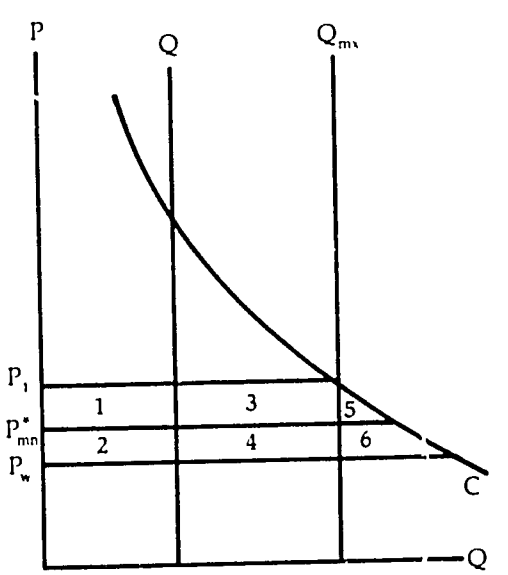


Figure 8 — Importing country with weak transport constraint



represents the world price. To prevent this windfall profit, the government is assumed to impose a tax (VL) on owners of such services just equal to the difference between the domestic market price (P_1) and the world market price (P_w):

$$VL = P_1 - P_w. \tag{26}$$

Such a tax produces a revenue gain for the government equal to areas 3 and 4. Producers profit too if transport facilities are insufficient. Their additional income is the sum of areas 1 and 2 in Figure 8. Consumers finally lose the sum of areas 1 through 6 because P_1 and not P_w is the market price.

In the market structure sketched in Figure 9, the sum of production and the import maximum, Q'_{mx}, is less than C^*_{mn}, the quantity necessary to hold market prices below the maximum allowable price P^*_{mx}. In the simulation model it is assumed that the gap ($C^*_{mn} - Q'_{mx}$) is filled by stock releases if security stocks are available:

$$DS = Q'_{mx} - C^*_{mn}. \tag{27}$$

Given this policy response consumers gain the areas 1, 2, and 3 from the stock release (DS). Producers lose areas 1 and 2, and area 3 constitutes a pure gain in consumers' surplus. The sum of areas 4 and 5 is the storage agency's revenue from selling DS at P^*_{mx}. However, if there are no security stocks to be drawn from, the assumed policy response is to levy a tax equal to ($P_2 - P_w$).

Finally, Figure 10 depicts the market structure in which production (Q) exceeds the consumption maximum (C^*_{mx}) so that price falls below the government's target price, P^*_{mn}. Because of the transport costs that separate the import price (P_w) from the export price (PX), explained in Chapter 4, the difference between Q and C^*_{mx} cannot be exported. It must be absorbed by the local market, causing prices to fall below P^*_{mn}. Since Q is greater than C^*_{mx} and less than C_{exp}, the quantity of production that would make exports profitable, the domestic market would clear at P_1 without government intervention.

In the model, however, it is assumed that the government will intervene to keep the domestic price at its lowest acceptable level, P^*_{mn}. One way to do that is to buy up the "excess supply" ($Q - C^*_{mx}$) at the price P^*_{mn}. The resulting stock changes are:

$$DS = Q - C^*_{mx}. \tag{28}$$

Note that this is not a market structure in which a variable levy would be effective.

Figure 9 — Importing country with severe transport constraint

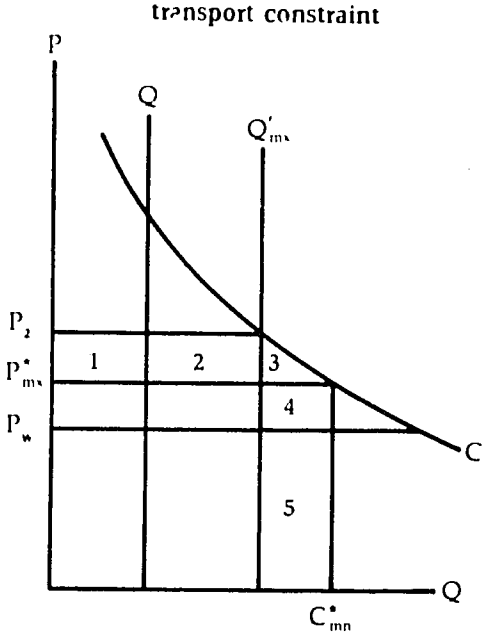
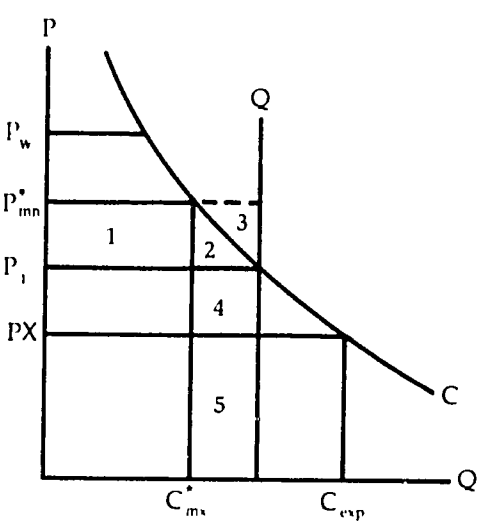


Figure 10 — Country with excess supply



Government intervention according to equation (28) implies that producers gain areas 1, 2, and 3 in Figure 10 and consumers lose areas 1 and 2. The financial cost to the government of its intervention is the sum of areas 2, 3, 4, and 5, that is, DS multiplied by the purchase price P^*_{mn}.

Parameters and Costs of Transport Services and Storage

Storage Costs

Table 7 summarizes the parameters determining the costs of security storage. Capital costs for the construction of storage facilities are calculated using straight-line depreciation over investment lives of 25 years.[25] These costs do not exhibit any economies of scale and they are calculated assuming that facilities are always used at 100 percent of capacity. Hence, since the investment cost of storage facilities is calculated to be $150 per metric ton, it can be assumed that the storage agency simply pays an annual rental of $6 per metric ton as the fixed cost for security storage.

Variable costs include sacks, labor, water, power, and pest protection. They are really transaction costs and are only incurred when grain is taken into storage or removed from storage; thus they are zero in years when stock changes are zero. The annual costs of losses due to pests and diseases are zero, an assumption which is generous but not too unrealistic.[26] Note, however, that the assumptions that variable costs for storage are incurred only when there are transactions and that there are zero losses are both favorable to reserve storage. Changing those assumptions to reflect more realistic conditions would reduce the profitability of such storage.

Table 7—Model storage parameters

Parameter	Symbol	Value
Fixed costs of storage	FC	$6 metric ton/year
Variable costs of storage	VC	$15 metric ton
Rate of interest on storage loans	r	10 percent/year
Subsidized loan rate for stock purchase	rs	2.5 percent/year

The interest costs of storage (I) are calculated from the balance of stock changes in the model. The borrowing rate for the storage agency's grain purchases (r) is 10 percent. When agencies buy or sell grain, they do so continuously over the course of the year. Interest costs on the loan to purchase grain of value V_t are given by:

$$I_t = V_t \cdot e^{r(t-1)}. \qquad (29)$$

Interest costs are cumulative; for example, grain bought in one year and held through the second year is held for one-and-a-half years.

Each country is assumed to have a stock of grain equal to 50 percent of its warehouse capacity at the beginning of the simulation period. The other 50 percent of the warehouse capacity is not used. The opening grain stock has been purchased in the world market with a low interest (2.5 percent) loan, assumed to come from aid donors. Therefore:

$$B_{i1} = P_{i1} \cdot 0.5 \cdot S_{i1} \cdot PW_{rs}, \qquad (30)$$

where B_{i1} is the present value cost of purchasing the opening stocks, S_{i1} is the total warehouse capacity in country i in year 1, P_{i1} is the c.i.f. price of grain, and PW_{rs} is a present worth factor.

The annual costs of the storage agency in country i (COST) are:

$$COST_{it} = (DS_{it} \cdot P^*_{it}) + |(VC \cdot DS_{it})| + FC + I_{it}. \qquad (31)$$

where P* denotes the price at which grain is being bought (P^*_{mn}) or sold (P^*_{mx}) by the storage agency.

The first term on the right-hand side can be positive or negative according to the sign of DS, the stock change. It will be positive—that is, the storage agency will lose money—when DS is positive; it will be negative—that is, the storage agency will make money—when DS is negative.

[25] See Appendix 2 for estimates of storage costs in the Sahel.

[26] Security storage in India reportedly incurs losses of only 1 percent.

For the first and the last year of the simulation period, equation (31) needs some modification. In year 1 the value of B_{it} (the cost of buying the stock) must be added to cost. In year 5 the value of the grain remaining in storage must be sold at the prevailing market price and the value subtracted from storage costs in that year.[27]

Because the storage scheme may operate in conjunction with the variable levy scheme and because that levy affects the prices at which the agency buys and sells, it is necessary to adjust the agency's costs for the distortions induced by the variable levy. These adjustments will not, in general, be important since when the agency buys or sells, the variable levy is usually zero. It is easy to see that this is so because the storage agency rules are designed to operate precisely when the variable levy is ineffective.

The net present value of storage costs over the five-year simulation period is given by:

$$NPV_i = \sum_t COST_{it} \cdot e^{-r(t-1)}. \qquad (32)$$

Security stock operations are naturally restricted by the fact that agencies cannot sell more grain than they own, or buy more grain than they can store. Therefore, if S_i is the constant warehouse capacity in the five-year period, OS_{it} is the grain stock at the beginning of year t, ES_{it} is the grain stock at the end of year t, and DS_{it} is the stock change in year t, then

$$ES_{it} = OS_{it} - DS_{it}; \qquad (33)$$

subject to the constraints

$$ES_{it} \leq S_i, \qquad (34)$$

and

$$DS_{it} \leq ES_{it-1}. \qquad (35)$$

Transport Constraints and Costs

Table 8 gives the model's specified values for the port service and transport maxima, and for transport costs. The maxima for the interior countries are set at 20,000-25,000 metric tons per month, with the exception of Mali. In Mali, with the Dakar-Bamako railroad and the Abidjan-Bamako road, the limit is set at 33,000 metric tons per month. Senegal and the Gambia do not appear to have serious limits on the amount of port services that can be mobilized for shipments, although that is perhaps not true of Mauritania.[28] One may object that this kind of transport constraint ignores completely the problem of the internal distribution of grain, a problem that is likely to be especially severe in the summer rainy season. This is mainly a matter of moving supplies before the rains make some roads impassable. Such considerations will affect the location of stocks, but with correct planning they should have little or no effect on the total quantity of stocks.

Operation and Costs of International Insurance Schemes

As was mentioned earlier, the benefits and costs of an international insurance scheme can be compared to those of a strictly national policy response, such as a variable levy or security stocks, only indirectly by contrasting the simulation results for cases 1 and 2. This section explains in more detail some of the characteristics of the insurance scheme approach to food security that is taken in this study.

There are two types of insurance schemes analyzed. One is designed to compensate participating members of the insurance scheme for the excess value of food im-

Table 8—Transport parameters

Country	Maximum Capacity	Cost
	(1,000 metric tons/year)	(U.S. $/metric ton)
Chad	200	150
Gambia	200	20
Mali	400	90
Mauritania	400	20
Niger	300	120
Senegal	800	20
Upper Volta	250	90

[27] No adjustment is made in the market price after this liquidation. The theoretically correct downward adjustment would reduce storage profits.

[28] See CILSS, Club of the Sahel, and Arup Partners, *Etude sur le Stockage*; Rogier, *Linear Programming*; and Stryker et al., "Large Scale Infrastructure."

ports (VM), where the excess is defined as the value of food imports above 110 percent of trend ($\hat{MB}$):[29]

$$VM = MB - 1.1 \cdot \hat{MB}, \text{ iff } VM > 0. \quad (36)$$

The second insurance scheme is designed to compensate for the marginal shortfalls in net foreign exchange earnings (VX), where net earnings (NX) are defined as total earnings minus the value of cereal imports:

$$VX = 0.9\hat{NX}_{it} - NX_{it}, \text{ iff } VX > 0. \quad (37)$$

For the actual calculations of this model it is assumed that compensation will only be paid if actual net earnings are less than 90 percent of this trend value ($\hat{NX}$).[30]

As for the relative costs of the two insurance schemes and the comparison with the nationally controlled policy instruments discussed earlier, some assumption has to be made about the net income transfer and subsidy of each insurance scheme. If the present value of compensation of either type is equal to the present value of repayments, then the facilities are pure stabilization funds. They provide no net subsidy and exist just to allow member countries to overcome temporary foreign exchange constraints. Because the Sahel countries do not often borrow in the international capital markets (Niger is an exception), and because their declining trends in grain consumption permit the inference that they have failed to import enough, it is fair to expect that either fund would have to be at least partly concessional.

Table 9 describes the parameters assumed for repayment of compensation from the import fund (Fund 1) and from the net export earnings fund (Fund 2). Several components of each fund are subsidized. There is a complete write-off of 50 percent of the disbursements, a grace period of five years on repayments, and a subsidized interest rate on repayments.

The value of compensation from Fund 1 is expressed as VM and the value from Fund 2 is VX; repayments to Fund 1 are REPVM and repayments to Fund 2 are REPVX, so that

$$REPVM = VM \cdot (1 - GE) \cdot CF \cdot SFF, \quad (38)$$

and

$$REPVX = VX \cdot (1 - GE) \cdot CF \cdot SFF. \quad (39)$$

The values of the subsidies in the two funds are the differences between their present values of disbursements and repayments. If SUBVM is the subsidy in Fund 1 and SUBVX is the subsidy in Fund 2, then

$$SUBVM = \sum_t VM_t \cdot e^{-r(t-1)} - \sum_t REPVM_{t+GP} \cdot e^{-Z(t+GP-1)}, \quad (40)$$

and

$$SUBVX = \sum_t VX_t \cdot e^{-r(t-1)} - \sum_t REPVX_{t+GP} \cdot e^{-Z(t+GP-1)}. \quad (41)$$

Note that the subsidies are increasing functions of the grace periods, of the differences between the market and subsidized interest rates, and of the shares of the grant elements in the value of disbursements.

Table 9—Insurance facility parameters

Parameter	Symbol	Value
Grace period	GP	5 years from date of disbursement
Interest rate	z	2.5 percent/year
Grant element	GE	50 percent of annual disbursements
Repayment period	RP	7 years beginning 5 years after the year of disbursement
Compensation factor	CF	$(1 + z)^{GP}$, necessary to account for the interest on the balance outstanding during the grace period
Sinking fund factor	SFF	Constant amount to be repaid annually given z and RP

[29] A higher value would, of course, reduce the level of insurance afforded and the amount of compensation.

[30] A smaller percentage will reduce the amount of compensation; a larger will increase it.

6

OPERATION OF SIMULATION MODEL AND RESULTS

Operation of the Model

The simulation experiments are conducted in two distinct steps. First, random samples of 300 observations[31] are generated for cereal production, world price of wheat, and export earnings for each of the seven countries under study and for each of the five years of the simulation period. Second, these data are used as basic inputs in the simulation of the model. The simulation extends over only five years because to use a larger period would risk making some unrealistic assumptions about the constancy of the model parameters as explained in Chapter 5. Although it is true that one might lose some information about possible runs in the data—that is, sequences of like-signed deviations from trend of some variables, grain production in particular—the probability of losing such information is low if one assumes, as is done here, that there is no serial correlation among the values of those variables.[32]

The model is simulated four times for each of the two cases mentioned earlier with each of the four simulations corresponding to a different level of security stocks during the first period of the simulation.[33] The simulations are conducted separately for each year and country. Table 10 reports values of the model's principal variables in 1981, the median year of the five-year simulation period, for the case without foreign exchange constraint. Table 11 shows the same variables for the case with a foreign exchange constraint.

The model is set up so that any one of the four market structures described in Chapter 5 can hold for any country and year. As a particular market structure materializes, the associated policy response discussed earlier is assumed to take effect immediately.[34]

To identify how sensitive the simulation results are to the price elasticity of demand for cereals, a central parameter of the model, all simulations are run twice, first using a price elasticity of −0.20 and then using a higher absolute elasticity of −0.50.

Simulation Results

The discussion of the simulation results may be organized around three basic questions: What degree of stabilization of grain consumption do the three policy instruments under study achieve under different economic conditions? What effects do these instruments have on income distribution? How efficiently do the proposed policy instruments achieve a given amount of food security?

Table 12 gives an overview of the stabilization effects of a variable levy or security stocks, and of both together. As can be seen clearly, the probability that consumption will fall more than 5 percent from trend is much greater when a foreign exchange constraint is in effect. This applies for all countries, coastal as well as interior and is independent of the price elasticity of demand or the size of buffer stocks. Also one can identify a generally higher probability of consumption shortfalls in the interior countries independent of the economic conditions being studied. This is because the interior countries are subject to tighter quantity constraints, in particular, the possibility of transport bottlenecks. When there is no foreign exchange constraint, increasing security stocks successively while ap-

[31] Experiments with sample sizes between 100 and 300 observations showed that the confidence intervals for the means of the simulated variables change little between sample sizes of 200 and 300, so it was assumed that it would be inefficient to go beyond 300.

[32] See Appendix 1 for an analysis of rainfall data in the Sahel that reinforces the point about the absence of serial correlation.

[33] The beginning grain stocks are assumed to be equal to 50 percent of the total storage capacity.

[34] Possible recognition, decision, or administrative lags are ignored for the purpose of simplicity.

Table 10—Simulated values of basic variables in median year without foreign exchange constraint

Country	World Price		Domestic Price		Consumption		Imports	
	Mean	Standard Deviation	Mean	Standard Deviation	Mean	Coefficient of Variation[a]	Mean	Coefficient of Variation
	(U.S. $/metric ton)				(1,000 metric tons)	(percent)	(1,000 metric tons)	(percent)
Chad	333	43	334	41	605	2.5	126	32.3
Gambia	203	42	203	36	108	3.5	44	19.3
Mali	283	42	291	52	1,142	3.3	263	38.7
Mauritania	203	42	203	36	190	3.5	149	7.6
Niger	293	43	314	142	1,263	6.8	149	85.4
Senegal	203	42	203	36	1,155	3.5	474	32.3
Upper Volta	283	42	282	74	1,266	5.0	120	86.3

Note: Variables are estimated at zero stock, with price elasticity of −0.2 for 1981.

[a] The coefficients of variation (cv) are the standard deviations (σ) of the relative deviations from trend. For example, for consumption,

$$cv = \sigma_{(c_t - \hat{c}_t)/\hat{c}_t}$$

where c_t is actual cereal consumption in year t and $\hat{c}_t$ is trend consumption in that year.

plying a variable levy has no measurable effect on consumption stability in the coastal countries, but it does reduce the probability of shortfalls in the interior countries. Hence, a variable levy seems to be sufficient for consumption stabilization in coastal countries as long as no foreign exchange constraint is binding.

The conclusions are very different when there is a foreign exchange constraint. In this case progressively raising stock levels reduces significantly the probability of consumption shortfalls in interior as well as coastal countries. Results for both groups of countries also depend on the specified price elasticity of demand, although a change in this parameter has only a minor effect on consumption stabilization. The direction of the effect, however, is predictable: the higher the price elasticity of demand, the less effectively do security stocks stabilize consumption. This is not surprising because at the lower elasticity price adjustments have little effect on consumption.

Next consider the effects of market interventions by import levies, security stocks, and windfall profit taxes on the income distribution in the Sahelian countries. The income distribution is measured in terms of the total income of producers,

Table 11—Simulated values of basic variables in median year with foreign exchange constraint

Country	Domestic Price		Consumption		Imports	
	Mean	Standard Deviation	Mean	Coefficient of Variation	Mean	Coefficient of Variation
	(U.S. $/metric ton)		(1,000 metric tons)	(percent)	(1,000 metric tons)	(percent)
Chad	367	92	596	4.1	117	25.4
Gambia	231	98	106	5.9	49	18.5
Mali	350	171	1,115	6.5	237	29.9
Mauritania	248	147	186	7.3	145	10.0
Niger	435	378	1,219	10.4	105	52.9
Senegal	281	262	1,116	8.2	436	25.8
Upper Volta	356	189	1,227	8.0	81	49.4

Note: Variables are simulated at zero stock with price elasticity of demand of −0.2. The foreign exchange constraint is specified by not allowing the value of food imports to exceed 110 percent of its trend value. World prices are as in Table 10.

Table 12—Probability of actual consumption falling 5 percent below trend for various sizes of beginning security stocks at elasticities of −0.20 and −0.50

Country	No Foreign Exchange Constraint; Beginning Security Stocks as Percent of 1977 Trend Consumption[b]				Foreign Exchange Constraint[a]; Beginning Security Stocks as Percent of 1977 Trend Consumption[b]			
	0%	5%	10%	20%	0%	5%	10%	20%
	(percent)				(percent)			
				Lower Elasticity: −0.20				
Chad	1.8	0.6	0.0	0.0	17.3	11.8	7.3	2.5
Gambia	0.0	0.0	0.0	0.0	19.1	15.2	12.4	6.3
Mali	3.9	2.2	1.5	0.5	22.7	19.1	16.1	9.9
Mauritania	0.0	0.0	0.0	0.0	20.4	17.5	14.5	9.7
Niger	11.5	8.2	5.7	3.6	32.1	27.4	23.8	16.4
Senegal	0.0	0.0	0.0	0.0	24.4	21.8	18.6	13.9
Upper Volta	5.3	3.0	1.6	0.4	29.1	23.0	17.8	11.4
				Higher Elasticity −0.50				
Chad	1.8	0.5	0.0	0.0	17.3	11.4	6.9	2.4
Gambia	0.0	0.0	0.0	0.0	19.1	15.5	12.3	8.3
Mali	3.9	2.1	1.3	0.3	22.7	18.7	15.3	9.5
Mauritania	0.0	0.0	0.0	0.0	20.4	17.7	14.9	10.8
Niger	11.5	7.2	5.4	3.1	32.1	22.2	23.5	16.4
Senegal	0.0	0.0	0.0	0.0	24.4	21.8	19.3	14.5
Upper Volta	5.3	2.6	1.3	0.5	29.1	22.3	17.0	10.8

[a] These are beginning stocks and are assumed to be equal to 50 percent of total storage capacity.
[b] Actual imports are not allowed to exceed 110 percent of trend imports.

which is simply the product of domestic grain production and price, and in terms of the consumers' surplus. The latter is calculated as

$$CS = (K/1 + \eta) \cdot (K^{1+\eta} - P_d^{1+\eta}) \cdot \quad (42)$$

where K is the intercept of the demand curve for cereals, η the corresponding price elasticity of demand, and P_d the domestic price of cereals. Producer income and consumer surplus are given as present values for the five years of the simulation.

For both measures, the income distribution resulting from market interventions for various amounts of beginning security stocks are compared to the income distribution that would result from free trade. Free trade is characterized for this purpose as trade with no market interventions, so that the world price of cereals equals a country's f.o.b. or c.i.f. price, depending on local supply and demand conditions.

As can be seen in Table 13, if there is no foreign exchange constraint, an increase in beginning stocks only slightly affects income compared to a situation of free trade without any market intervention. This applies equally to the coastal and interior countries and reflects the results on consumption stabilization found in Table 12. Table 13 also shows that the results are hardly sensitive to a change in the price elasticity of demand. Compared to the case where there is no foreign exchange constraint, the introduction of such a constraint (Table 14) redistributes income from consumers to government and producers in the absence of security stocks. This is equivalent to granting producers a large amount of protection, up to 22 percent for producers in coastal countries and between 10 and 42 percent[35] to producers in the interior countries.

[35] Because the values of producers' incomes in the Stock 0 columns are all equal to $(P_d \cdot Q)/(P_w \cdot Q)$, where Q is cereal output, P_d is domestic price, and P_w is world price, they can be interpreted as minimal protection coefficients (NPCs) in percentage terms.

Table 13--Producer income and consumer surplus without foreign exchange constraint at elasticities of −0.20 and −0.50

Country	Producer Income					Consumer Surplus				
	Free Trade	Market Interventions at Stock Level[a]				Free Trade	Market Interventions at Stock Level			
		0%	5%	10%	20%		0%	5%	10%	20%
	(U.S. $ million 1979)	(percent of free trade column)				(U.S. $ million 1979)	(percent of free trade column)			
					Lower Elasticity: −0.20					
Chad	656	100.0	100.0	100.9	100.9	3,168	99.6	99.7	99.7	99.7
Gambia	54	100.0	99.9	99.9	99.9	45	100.0	100.0	100.0	100.0
Mali	1,016	102.2	101.9	101.7	101.6	10,861	99.6	99.7	99.7	99.7
Mauritania	35	100.0	99.5	99.5	99.5	240	100.0	100.0	100.0	100.0
Niger	1,231	109.3	108.2	107.6	107.1	13,311	98.7	98.9	99.0	99.1
Senegal	566	99.9	99.9	99.9	99.9	10,024	100.0	100.0	100.0	100.0
Upper Volta	1,248	103.8	103.7	103.9	104.1	13,058	99.5	99.5	99.5	99.5
					Higher Elasticity: −0.50					
Chad	656	100.4	100.4	100.3	100.4	7,850	99.9	99.9	99.9	99.9
Gambia	54	99.9	99.9	99.9	99.9	312	99.8	99.8	99.8	99.8
Mali	1,017	101.0	100.9	100.8	100.7	19,240	99.9	99.9	99.9	99.9
Mauritania	35	100.0	100.0	100.0	100.0	835	99.9	99.9	99.9	99.9
Niger	1,281	103.1	102.8	102.7	102.7	23,031	99.7	99.8	99.8	99.8
Senegal	566	100.0	100.0	100.0	100.0	15,290	99.9	99.9	99.9	99.9
Upper Volta	1,284	101.9	101.9	102.0	102.1	22,302	99.8	99.8	99.8	99.8

[a] Stock levels are given as percentages of 1977 trend consumption of cereals.

Table 14—Producer income and consumer surplus with foreign exchange constraint at elasticities of −0.20 and −0.50

Country	Producer Income					Consumer Surplus				
	Free Trade	Market Interventions at Stock Level[a]				Free Trade	Market Interventions at Stock Level			
		0%	5%	10%	20%		0%	5%	10%	20%
	(U.S. $ million 1979)	(percent of free trade column)				(U.S. $ million 1979)	(percent of free trade column)			
					Lower Elasticity: −0.20					
Chad	657	110.7	108.7	107.4	106.3	3,177	97.0	97.5	97.9	98.2
Gambia	54	110.6	108.6	107.3	105.2	45	77.3	81.2	84.0	87.7
Mali	1,024	117.0	114.2	112.1	109.1	10,850	97.6	98.0	98.3	98.7
Mauritania	35	114.7	112.5	110.8	108.5	240	89.2	90.6	91.9	93.5
Niger	1,237	142.2	136.2	131.8	125.4	13,303	95.9	95.6	96.1	96.9
Senegal	566	122.2	119.0	116.5	112.8	10,024	97.2	97.6	97.9	98.4
Upper Volta	1,255	125.2	121.8	119.4	116.0	13,050	97.1	97.5	97.7	98.1
					Higher Elasticity: −0.50					
Chad	658	103.5	102.9	102.5	102.2	7,848	99.6	99.6	99.7	99.7
Gambia	54	103.0	102.5	102.3	101.8	312	98.9	99.0	99.1	99.2
Mali	1,026	104.7	103.9	103.4	102.6	19,229	99.6	99.7	99.1	99.8
Mauritania	35	103.7	103.2	102.8	102.2	835	99.1	99.2	99.3	99.4
Niger	1,300	110.0	108.8	108.0	106.7	23,007	99.3	99.3	99.4	99.5
Senegal	566	105.8	105.1	104.6	103.9	15,290	99.5	99.5	99.6	99.6
Upper Volta	1,293	107.9	107.1	106.5	105.6	22,291	99.4	99.5	99.5	99.6

[a] Stock levels are given as percentages of 1977 trend consumption of cereals.

Increasing buffer stocks gradually from zero to 20 percent of 1977 trend consumption tends to redress the income effects of the foreign exchange constraint. The positive protection afforded producers is reduced and consumers regain some of their surplus lost when the exchange constraint was introduced.

Table 14 shows that at a higher price elasticity of demand for cereals, the protection afforded to producers is perceptibly lower in both coastal and interior countries. Actually, the level of protection is only slightly higher than in the absence of a foreign exchange constraint, as shown in Table 13. This is particularly valid when beginning security stocks are 20 percent of 1977 consumption. It contrasts markedly with the outcome for a lower price elasticity. Here, a foreign exchange constraint induces a considerable transfer of income to producers compared to the case where no subconstraint is binding.

In other words, a foreign exchange constraint on top of an import levy and transport constraint only gives producers perceptibly greater protection than any combination of import levies and transport constraints alone if the price elasticity of demand is low. If the price elasticity is relatively high, a foreign exchange constraint does not increase the protection enjoyed by producers considerably.

Whether a foreign exchange constraint exists or not, one can determine whether the net effect of a variable levy or security storage is to increase or decrease the sum of producers' income and consumers' surplus and how this change compares to storage costs. Such a comparison enables one to see whether the sum of net benefits generated by the two policy instruments exceeds that of their net costs. This is done in Table 15 and 16, which give benefit/cost ratios for different sizes of security stocks for both Case 1 and Case 2. These ratios are typically much less than 1.0 in the absence of a foreign exchange constraint; they are somewhat larger but seldom exceed 1.0 in the presence of one. At the lower elasticity this does not, however, mean that the foreign exchange restriction together with beginning stocks of 20 percent of 1977 trend consumption increases social income more than if there were no foreign exchange constraint. Rather, it means that when that constraint is absent income is higher for each size of stock than when it is present.

The benefit/cost ratios of Table 15 and 16 show that gains from consumption stabilization, although consistently positive, are always much smaller than the costs of running the storage operations if there is no foreign exchange constraint. In no country does the ratio exceed 0.30 for any size stock. This result is independent of the price elasticity of demand. Storage is, however, much less unprofitable for the landlocked countries, especially when there is a foreign exchange constraint. The profitability is highest in Niger, where the two largest amounts of beginning security stocks can be said to provide a competitive return.

If one assumes that each country would not finance food import bills above 110 percent of trend (in other words, if a foreign exchange constraint exists), then some intervention, whether grain reserves or foreign exchange assistance, is necessary to prevent consumption shortfalls. The economic comparison is then between the value of assistance in import insurance or in subsidies to grain reserves necessary to attain specified amounts of food security.

As noted above, the relative efficiency of import insurance and security storage is analyzed implicitly by comparing the results for Case 1, where there is no foreign exchange constraint, to the ones for Case 2, where there is a foreign exchange constraint. More explicitly, Case 1 represents the situation where foreign exchange assistance has been supplied to pay for enough imports to stabilize consumption; Case 2 represents the situation without any insurance scheme, where each country has to rely solely on security stocks to stabilize consumption.

Table 17 shows the relative efficiency of beginning security stocks of 20 percent of 1977 trend consumption compared to the two food insurance schemes discussed earlier. Each has about the same stream of net benefits.

The probability of actual consumption falling below 95 percent of trend consumption is considerably lower for the two food insurance schemes. Only for Niger and Upper Volta does this probability exceed the 5 percent mark. For the grain reserves alternative, however, the probability is always greater than 5 percent except for Chad.

The food insurance scheme also does more to reduce the variability of domestic prices as measured by its coefficient of

Table 15—Benefits and costs of different levels of security stocks without foreign exchange constraint at elasticities of −0.20 and −0.50

Country	Net Benefits Without Security Stocks[a]	Change in Net Benefits at Stock Level			Costs of Stock Level			Ratio of Changes in Net Benefits and Costs at Stock Level		
		5%	10%	20%	5%	10%	20%	5%	10%	20%
				(1979 U.S. $)						
					Lower Elasticity: −0.20					
Chad	−391	17	37	62	2,453	4,904	9,814	0.007	0.008	0.006
Gambia	−14	15	27	49	396	802	1,614	0.037	0.033	0.030
Mali	−1,620	79	211	452	3,836	7,771	15,980	0.021	0.027	0.024
Mauritania	−24	28	52	951	794	1,605	3,228	0.035	0.032	0.029
Niger	−10,510	775	2,131	4,983	4,788	9,726	19,772	0.162	0.219	0.252
Senegal	−195	154	275	498	3,924	7,954	18,002	0.039	0.035	0.028
Upper Volta	−2,659	296	766	1,390	5,402	10,668	20,861	0.055	0.072	0.067
					Higher Elasticity: −0.50					
Chad	−708	99	193	367	3,609	7,176	14,152	0.027	0.027	0.026
Gambia	−315	60	118	227	448	1,028	1,864	0.134	0.115	0.122
Mali	−3,333	238	470	875	5,674	11,300	22,931	0.042	0.042	0.039
Mauritania	−556	120	234	452	899	1,830	3,741	0.133	0.128	0.121
Niger	−4,396	442	040	2,153	6,936	13,795	27,031	0.064	0.076	0.080
Senegal	−3,420	603	178	2,264	4,454	9,055	18,490	0.135	0.130	0.122
Upper Volta	−2,568	289	608	1,106	7,107	14,036	27,074	0.041	0.013	0.041

[a] Net benefits without stocks are the sum of changes in producers' income, consumers' surplus, and government revenue resulting from imposition of a variable levy.

Table 16—Benefits and costs of different levels of security stocks with foreign exchange constraint at elasticities of −0.20 and −0.50

Country	Net Benefits Without Security Stocks[a]	Change in Net Benefits at Stock Level			Costs of Stock Level			Ratio of Changes in Net Benefits and Costs at Stock Level		
		5%	10%	20%	5%	10%	20%	5%	10%	20%
				(1979 U.S. $)						
				Lower Elasticity: −0.20						
Chad	−3,355	223	614	1,187	1,532	3,423	7,823	0.146	0.179	0.152
Gambia	−427	32	83	183	325	667	1,392	0.099	0.124	0.131
Mali	−12,693	488	1,588	4,301	2,398	5,104	11,315	0.204	0.311	0.380
Mauritania	−1,460	65	187	414	679	1,395	2,880	0.096	0.134	0.144
Niger	−57,965	2,097	6,435	16,121	5,225	4,837	11,288	0.401	1.33	1.428
Senegal	−21,529	650	1,945	5,167	2,625	5,425	11,428	0.248	0.359	0.452
Upper Volta	−23,732	1,093	3,155	7,093	2,574	5,636	12,694	0.424	0.560	0.559
				Higher Elasticity: −0.50						
Chad	−1,250	184	382	646	2,585	5,247	10,618	0.071	0.073	0.061
Gambia	−302	51	105	215	410	833	1,673	0.124	0.126	0.129
Mali	−3,319	408	934	1,979	4,317	8,602	12,344	0.095	0.109	0.114
Mauritania	−403	88	181	387	895	1,817	3,681	0.098	0.100	0.105
Niger	−13,787	701	1,892	4,395	4,716	9,350	18,593	0.149	0.202	0.236
Senegal	−7,369	646	1,414	2,926	3,733	7,590	15,481	0.173	0.186	0.189
Upper Volta	−8,749	498	1,192	2,440	4,688	9,340	18,585	0.106	0.128	0.132

[a] Net benefits without stocks are the sum of changes in producers' income, consumers' surplus, and government revenue resulting from imposition of a variable levy.

Table 17—Efficiency of grain reserves versus food insurance in stabilizing consumption at elasticities of −0.20 and −0.50

Country	Grain Reserves Without Financial Assistance				Food Insurance Without Grain Reserves			
	Grain Reserves	Probability of Consumption Falling 95 Percent Below Trend	Coefficient of Variation of Domestic Price	Net Benefits[a]	Probability of Consumption Falling 95 Percent Below Trend	Coefficient of Variation of Domestic Price	Net Benefits: Food Import Assistance[b]	Net Benefits: Net Export Assistance[c]
	(1,000 metric tons)	(percent)		(U.S. $ million)	(percent)		(U.S. $ million)	
				Lower Elasticity: −0.20				
Chad	120	2.5	16.2	3,824	1.8	13.2	3,821	3,825
Gambia	20	6.3	29.1	98	0.0	17.0	97	92
Mali	200	9.9	28.9	11,855	3.9	18.3	11,845	11,830
Mauritania	40	9.7	47.2	270	0.0	17.0	270	264
Niger	240	16.4	58.5	14,487	11.5	41.9	14,477	14,494
Senegal	200	13.9	53.2	10,562	0.0	17.0	10,556	10,568
Upper Volta	240	11.4	31.8	14,276	5.4	23.4	14,259	14,268
				Higher Elasticity: −0.50				
Chad	120	2.4	7.9	8,492	1.8	7.9	8,492	8,496
Gambia	20	8.3	11.7	364	0.0	8.8	364	358
Mali	200	9.5	10.9	20,237	3.9	8.9	20,225	20,211
Mauritania	40	10.8	15.2	866	0.0	8.8	865	858
Niger	240	16.4	18.2	24,279	11.5	15.0	24,753	24,269
Senegal	200	14.5	17.3	15,837	0.0	8.8	15,820	15,832
Upper Volta	240	10.8	11.8	23,560	5.3	10.3	23,540	23,550

[a] Sum of producers' income and consumers' surplus minus financ torage losses.

[b] Sum of producers' income and consumers' surplus minus food insurance value

[c] Sum of producers' income and consumers' surplus minus net export earnings insurance value.

variation. The superiority of the food insurance scheme in this respect is particularly pronounced for the coastal countries.

Table 18 presents a similar conclusion from a slightly different perspective. The first column shows the amount of security reserves roughly necessary to ensure that the probability of consumption falling below 95 percent of trend does not exceed 5 percent. It can be seen from the second column, however, that even with a security stock of 500,000 metric tons, Niger and Senegal are not able to stabilize their grain consumption sufficiently. This is similar to the situation depicted in Table 17, where a food insurance scheme alone does not guarantee that consumption will not fall below 95 percent of trend. The right-hand side of Table 18, however, shows that holding a smaller security stock in conjunction with a food insurance scheme can stabilize consumption within the prescribed probability band.

A common argument in favor of grain reserves is that they conserve foreign exchange. The argument can be tested by comparing food import assistance (Table 17) to the unsubsidized foreign exchange costs of grain reserves.[36] Those costs are the sum of the purchase price of the opening stock, the traded components of warehouse investment and stock operations, and the financial opportunity cost of the foreign exchange used to purchase the stock. The latter is calculated by assuming that the money used to finance the opening stock is foreign exchange, which governments can hold as such or which they can hold as grain. If that money is held as grain, which cannot be easily reconverted into foreign exchange, then its financial opportunity cost is the difference between its present value at market interest and its present value if it is not invested in foreign exchange. The foreign exchange savings (FXS) of grain reserves are counted as:

$$FXS = MB_1 - VM - MB_2 \,. \qquad (43)$$

where MB_2 is the import bill for grain reserve holdings, MB_1 is the import bill in the case of food insurance, and VM is the import compensation awarded.

Foreign exchange costs (FXC_i) are given by:

$$FXC_i = [(P_{i1} \cdot s_{i1}/2) \cdot (1 + [1 - v^5])] + [(s_{i1} \cdot FC) \cdot (1 - v^5/i)] + \sum_t [(DS_{it} \cdot VC/2) \cdot v^t] - FXS_i \,. \qquad (44)$$

where

P_{i1} = c.i.f. price of grain for country i and year 1, in dollars per metric ton;

s_{i1} = storage capacity for country i and year 1, in metric tons;

v^t = annuity factor equal to $1/(1 + i)^t$;

DS_{it} = annual stock change for country i and year t, in metric tons;

FC = fixed storage costs equal to $6 per metric ton per year (100 percent foreign component); and

VC = variable storage costs equal to $15 per metric ton per year (50 percent foreign exchange component).

The term $(P_{i1} \cdot s_{i1})$ is divided by 2 because the opening grain stock is only 50 percent of s_{i1}.

The equation for deriving import insurance figures is:

$$PVM_i = \sum_t VM_{it} \cdot v^t \,, \qquad (45)$$

where VM is given by equation (36).

Net export insurance figures are derived from the following equation:

$$PVX_i = \sum_t VX_{it} \cdot v^t \,, \qquad (46)$$

where VX is given by equation (37).

Table 19 shows that the foreign exchange costs of reserves are substantially higher than those of import insurance. Even if there is no financial opportunity cost of holding grain reserves, food import assistance requires only 60 percent of the foreign exchange needed to establish reserves. Net export assistance costs less than food import assistance.

A basic question in the analysis of food insurance is: how much insurance can countries get by holding specified amounts of foreign exchange? The compensation

[36] Food import compensation is the marginal foreign exchange cost above the 110 percent of trend import value, so that it is the relevant standard against which to compare foreign exchange costs of grain reserves.

Table 18—Grain reserves necessary to achieve 95 percent probability of consumption stabilization at an elasticity of −0.20

Country	Sole Reliance on Grain Stocks in Case of Foreign Exchange Constraint				Grain Stocks Used as Supplement to Food Insurance				
								Net Benefits	
	Grain Reserves	Probability of Consumption Falling 95 Percent Below Trend	Coefficient of Variation of Domestic Price	Net Benefits	Grain Reserves	Probability of Consumption Falling 95 Percent Below Trend	Coefficient Variation of of Domestic Price	Food Import Assistance	Net Export Assistance
	(1,000 metric tons)	(percent)		(U.S. $ million)	(1,000 metric tons)	(percent)		(U.S. $ million)	
Chad	90	4.4	17.5	3,826	0.0	1.8	13.2	3,821	3,825
Gambia	35	2.8	25.6	96	0.0	0.0	17.0	97	92
Mali	350	4.7	23.0	11,843	0.0	3.9	18.3	11,845	11,831
Mauritania	80	5.3	42.1	267	0.0	0.0	17.0	270	266
Niger	500	8.6	41.7	14,481	150.0	5.0	27.7	14,471	14,486
Senegal	500	5.3	42.5	10,547	0.0	0.0	17.0	10,556	10,568
Upper Volta	400	5.0	24.3	14,264	20.0	4.5	21.9	14,258	14,267

Table 19—Foreign exchange costs of food insurance and grain reserves at required reserve stock levels and at an elasticity of −0.20

Country	Grain Reserves[a]		Foreign Exchange Assistance	
	With Interest Cost	Without Interest Cost	Import Insurance	Net Export Insurance
	(U.S. $ million)			
Chad	22.9	17.3	13.9	9.7
Gambia	6.2	4.9	1.7	7.4
Mali	77.1	58.6	31.5	46.1
Mauritania	15.5	12.5	3.8	10.6
Niger[b]	114.6	87.2	54.1	38.0
Senegal	93.6	74.8	33.7	21.7
Upper Volta[b]	88.1	67.0	43.7	34.6
Total	418.0	322.3	182.4	168.1

[a] Stocks are in thousand metric tons: Chad (90), Gambia (35), Mali (350), Mauritania (80), Niger (500), Senegal (500), and Upper Volta (400).

[b] Because Niger and Upper Volta could not achieve 95 percent stabilization probabilities without grain reserves, the values of import insurance and net export insurance shown here for those countries are with reserve capacities of 150,000 metric tons for Niger and 20,000 metric tons for Upper Volta.

paid to countries can be imagined as an insurance premium that countries would receive for import bills above 110 percent of trend or for net export earnings below 90 percent of trend. The mean value of compensation would, therefore, cover 50 percent of the insured risks. A value of compensation roughly two standard deviations above the mean would cover 95 percent of insured risks.

Table 20 shows the amounts of foreign exchange necessary to cover the five-year present values of import bills above 110 percent of trend or of net export earnings less than 90 percent of trend. To cover excess food import bills half of the time would require between 2.0 percent (Mauritania) and 34.4 percent (Upper Volta) of 1979 trend export earnings. To assure 95 percent coverage—that is, to assure coverage in 95

Table 20—Foreign exchange holdings necessary to achieve different insurance probabilities with no stocks and at an elasticity of −0.20

Country	1979 Trend Export Earnings	Holdings Necessary to Achieve Specified Probabilities[a]					
		50%		95%		99%	
		Food Import Assistance	Net Export Assistance	Food Import Assistance	Net Export Assistance	Food Import Assistance	Net Export Assistance
	(U.S. $ million, 1979)						
Chad	133	13.9	9.7	36.5	28.3	43.6	34.1
Gambia	74	1.7	7.4	5.6	22.3	6.9	26.9
Mali	156	31.5	46.1	83.5	118.5	99.8	141.2
Mauritania	192	3.8	10.6	16.6	34.1	20.7	41.5
Niger	243	54.1	37.8	66.6	102.7	141.5	123.0
Senegal	996	33.7	21.7	100.6	91.6	121.6	113.5
Upper Volta	127	43.7	34.6	98.4	87.3	115.5	103.9

[a] The values are 1979 present values. The 50 percent probability is the mean value of compensation. Since the distributions of compensation are normal, this value is greater than 49.99 percent of compensation values. The 95 percent value is $X = \bar{X} + 1.96 \cdot S_x$, the 99 percent value is $X = \bar{X} + 2.575 \cdot S_x$.

of 100 years—would require between 7.6 percent (the Gambia) and 77.5 percent (Upper Volta).

It is likely that the coastal countries could hold enough foreign exchange reserves to insure themselves against excess food import bills. To achieve such security in 95 of 100 years each country would have to set aside (at most) 10 percent of its 1979 trend export earnings for excess import bills between 1979 and 1983 if such reserves were invested at a 10 percent real rate of return. This conclusion holds even if there are no grain reserves.

It is unlikely that the four interior countries could set aside enough of their 1979 trend earnings to achieve an equal insurance probability. To do so would require between 27 percent (Chad and Niger) and 77 percent (Upper Volta) of 1979 trend earnings for the period 1979-83. These countries would probably require some external assistance to meet their food import bills, apart from whatever contribution they could make.

In sum, comparing the effects of grain reserves to those of foreign exchange compensation shows that compensation produces higher net economic benefits if the two policies are compared at equal levels of consumption stability. Readers are reminded that several assumptions favor grain reserves in the comparison, so that, if anything, grain reserves would be more costly than shown here. Those assumptions are: zero storage losses, full storage capacity use, subsidized interest on the opening grain stock, and zero variable cost of stock operation when there are no stock changes.[37] The model is also biased in favor of storage in that sales of grain purchased with foreign exchange compensation are excluded from the cost-benefit accounting, so that the value of that compensation is a net cost.

The model also enables evaluation of the argument that grain reserves save foreign exchange. Comparing reserves to foreign exchange compensation solely on the basis of foreign exchange costs shows that net export assistance is cheapest, followed by food import assistance and grain reserves. The foreign exchange cost of grain reserves necessary to achieve a 95 percent consumption probability would be about 149 percent greater than net export assistance and 129 percent greater than food import assistance. There is also the possibility that grain reserves would incur foreign exchange costs excluded from this model. Because reserves, combined with a foreign exchange limit, would raise domestic producer prices of cereals while prices of export crops stayed constant, one might expect some production to switch from export crops to cereals. This supply response would then presumably produce a fall in export earnings that should be counted as part of the foreign exchange cost of grain reserves.

[37] There is another assumption as well. It is that made in CILSS and Club of the Sahel, *Marketing*, pp. 296-297. To operate security stocks, agencies must have adequate turnover in their commercial operations to physically rotate the grain held in long-term reserves.

7

EVALUATION OF STABILIZATION POLICIES AND CONCLUSIONS

Evaluation of Policy Instruments

Trade Policies

A fundamental result of the analysis is that if trade is restricted only by a variable levy and if foreign exchange assistance is provided, consumption stability can be achieved in every country but Niger without grain reserves. The action of the variable levy then incurs a small social welfare loss, which is borne by grain consumers in most countries.

If there is a foreign exchange constraint so that the annual value of grain imports cannot exceed 110 percent of trend value, then consumption instability increases dramatically in the absence of security storage. Also, foreign exchange rationing for food imports, which may follow in this kind of situation, would incur greater deadweight losses and destabilize consumption more than where trade is only restricted by a variable import levy.

These results may make a contribution to the argument about marketing policy. If it is indeed an official objective to restrict trade between the countries of the region and on world markets, then the instability of consumption will increase at any stock level, and the costs of insuring consumption stability will rise because larger stocks will be necessary. There is a great danger that the eagerness of donors to pay for interventions at all levels of marketing will contribute to instability, partly by restricting the quantity of international trade and partly by imposing policies that distort prices.[38]

What is true of restrictions on extra-regional trade is also true of restrictions on intraregional and intranational trade. Public impediments to commodity flows, whether the prohibition of private trade or the imposition of uniform price policies, prevent price adjustments from one place and time to another.[39] By so doing, they make consumption in some areas more unstable than it would be otherwise. It is quite possible that liberalization of domestic grain trade could reduce the total demand for stocks, even at current levels of production and world price instability. In this regard, recent initiatives undertaken by the Communauté Economique d'Afrique de l'Ouest to reduce barriers to grain trade among members are to be encouraged.

Security Storage

The decision to increase stocks above the current levels depends on the availability of financing for stocks and for other types of assistance. Table 21 shows the stabilization

[38] Some protectionism arises because some believe that there is a demonstration effect from imports of wheat and rice. Philippe Richard argues that this growth impedes attainment of food self-sufficiency and that public agencies should adopt policies to favor, that is, to protect, local cereals, such as encouraging the development of new processing technologies, and "by controlling as well as possible cereal imports (wheat and rice) by adding to internal production (Philippe Richard, "La Commercialisation des Céréales," paper presented at CILSS Colloquium on Cereals Policy in the Sahel, Nouakchott, 1979, p. 54. To be sure, Richard adds that public agencies must respect "a price equilibrium between local and imported products . . ."

Another paper presented at that conference argues that "a more intensive and modernized agriculture oriented toward . . urban markets" must be protected just as European agriculture was against American wheat. See Jacques Giri, Soumana Traoré, Claude Marsolat, "La Politique des Prix des Céréales dans la Sahel," a paper presented at the CILSS Colloquium on Cereals Policy in the Sahel, Nouakchott, 1979, p. 20.

[39] Mali, Senegal, and Niger now ban private trade except by licensed traders. Mali and Niger, at least, attempt to ensure uniform price policies throughout their countries. The latter policy has the expected effect of depriving remote areas of food except from government stores. FAO, *National and Regional Security Grain Stocks in the Sahel. A Feasibility Study Carried Out at the Request of CILSS*, 9 vols. (Rome: FAO, 1980). Summary: 5 recommends a single transaction price for cereals.

Table 21—Stabilization effects of current security stocks with and without financial assistance at an elasticity of −0.20

Country	Current Grain Reserves[a]	Foreign Exchange Constraint: Probability of Consumption Falling Below 95 Percent of Trend	Foreign Exchange Constraint: Coefficient of Variation of Domestic Price[b]	Foreign Exchange Constraint: Net Benefits	Foreign Exchange Assistance: Probability of Consumption Falling Below 95 Percent of Trend	Foreign Exchange Assistance: Coefficient of Variation of Domestic Price	Foreign Exchange Assistance: Net Benefits: Food Import Assistance	Foreign Exchange Assistance: Net Benefits: Net Export Assistance
	(1,000 metric tons)	(percent)		(U.S. $ million)	(percent)		(U.S. $ million)	
Chad	38.0	10.5	21.4	3,828	0.5	12.5	3,816	3,820
Gambia	4.5	15.6	31.7	98	0.0	17.0	97	91
Mali	58.5	18.5	39.4	11,559	1.9	16.3	11,840	11,825
Mauritania	30.0	12.0	50.0	271	0.0	17.0	268	261
Niger	45.0	28.4	77.0	14,481	8.9	37.1	14,474	14,490
Senegal	64.0	21.2	67.0	10,566	0.0	16.9	10,551	10,562
Upper Volta	20.0	27.0	46.2	14,281	4.5	22.0	14,258	14,267

[a] These are the existing stocks shown in Food and Agriculture Organization of the United Nations, *National and Regional Security Grain Stocks in the Sahel: A Feasibility Study Carried Out at the Request of CILSS*, 9 vols. (Rome: FAO, 1980). Summary: 7 for Mali, Niger, Senegal, and Upper Volta. For Chad, Gambia, and Mauritania (where existing stocks are 5,000 metric tons or fewer) the stock shown includes proposed capacity.

[b] The coefficient of variation (cv) is calculated as a five-year average of cv as defined in Table 10.

effects and net economic benefits of current storage levels with and without foreign exchange assistance and the amount of financial assistance that would have to be provided under both insurance schemes studied.

Though the net economic benefits are slightly less if financial assistance is provided than if it is not, prices and consumption can be much more stable if it is. The grain reserves with financial assistance are able to meet the minimum consumption requirements 95 percent of the time everywhere but Niger. The same reserves without it are able to meet the same requirements only 88-90 percent of the time in only two countries (Chad and Mauritania). Comparing the stability achieved by planned reserves with financial assistance to that achieved by much larger reserves with a foreign exchange constraint (Table 21) shows that the smaller reserves together with financial assistance would produce higher food security and more price stability in every country but Niger than does simple reliance on grain reserves. Domestic producer prices would be higher if no assistance were given than if it were, which might produce distortions in associated markets. The only country for which further stock investment might be justified is Niger. In every other country planned stocks can provide basic consumption stabilization if foreign exchange assistance is available.

Farmers hold reserves throughout the Sahelian region and these reserves have not been accounted for in the simulation. Such reserves, if they could be accurately measured, might be quite small as shares of total output.[40] To the extent that annual carryouts exist they would tend to provide more stability than the models show. Such reserves are a further argument against increasing public stocks, because increases in public stocks might displace private reserves and thus make no net contribution to total stocks. The possible importance of this displacement has been demonstrated for the United States[41] and there is no reason to think a similar effect would not occur in the Sahel.

Foreign Exchange Assistance

Sahelian countries can increase their food security by participating in a food insurance or compensatory financing facility. The benefits from such a facility, however, may be open to certain doubts which need to be dispelled. There is the commonly noted problem of production and import reporting. Although this is not insuperable, its resolution requires more cooperation among countries—cooperation necessary to diminish fears of cheating. Fear of moral hazard is one reason why CILSS members might reject a truly regional grain reserve; it is a legitimate fear that can be appeased only by having established procedures for measuring and reporting production and trade statistics. Current delays in publication of such data might be cited as evidence for the impracticality of a financial facility, but there is no reason why such delays must be permanent.

There is also the probability that the world prices used to estimate the values of compensation will change after requests are submitted. International prices vary throughout the year and such changes will alter the purchasing power of specified awards. There is some reason to expect that the implementation of such a facility among many countries (as in the IMF scheme) might raise the trend of international prices. It is not clear, however, that the facility would change prices within years, so it seems reasonable to assert that average changes in the purchasing power of compensation would be zero.

There is a third and more subtle form of moral hazard to be found in expansionist macroeconomic policies or distorted price policies that expand consumption and imports. Correction of macroeconomic policies would be beyond the facility's mandate, but clearly some agreement can be found on common sale prices of food bought with compensation and on official prices for domestic consumption. This agreement would account for differences in cost and price structures, especially between coastal and

[40] See John W. Sutter, "Social Analysis of the Nigerian Rural Production" in *Niger Agricultural Sector Assessment* (Washington, D.C.: U.S. Agency for International Development, 1979), pp. 58-65, which argues that producers' stocks in the Zinder area of Niger were not sufficient to last from one harvest to the next in 1977/78. Sutter reports that in French ethnographic literature it was said that farmers in the area had stocks for one to three years during the 1960s.

[41] See Anne E. Peck, "Implications of Private Storage for Grains for Buffer Stock Schemes to Stabilize Prices," *Food Research Institute Studies* 16 (No. 3, 1977) for an exposition of the displacement argument.

interior nations, but it does not seem that defining just rules-of-thumb would be difficult.

Grain bought with compensation may not arrive in time to prevent shortfalls, and this can be an argument against food insurance and for a financial facility. This argument is overrated. If the reserves shown in Table 21 are actually stored, they would allow any country an adequate period in which to plan imports, even it it has a serious foreign exchange constraint. Even if every country experienced a 30 percent production shortfall in 1981, import prices rose by 30 percent, and only a six-month's supply of imports were available, one could still count on at least an eight-month's supply of cereal everywhere but Mauritania. This result applies to the case where no foreign exchange constraint is effective. In the alternative case, where a foreign exchange exists, the minimum supply of cereals available would still extend over a seven-month period everywhere except Mauritania. These are minimum periods, during which arrangements could be made to import for the remaining months. Not only do these periods seem adequate to arrange for additional imports and for release of stocks, but they can be extended by increasing import orders with confidence that compensation will be made for the increased import bill.

Some Additional Considerations

Aspects of a Regional Approach to Food Security

The apparent adequacy of national stocks in most countries is an argument against not only the establishment of more national stocks but against the establishment of regional stocks, if those regional stocks would supplement, not supplant, national stocks.[42] If countries are to exploit all the theoretical gains from risk sharing, it will be necessary to pool all their risks. This implies that retaining a large share of national reserves in total reserves (that is, national plus regional reserves) would reduce the shared risk and the shared benefits. Although regional reserves could exploit some of the imperfect correlations among production shortfalls in the region, the possible savings from aggregation might be dissipated entirely by increased costs of transport, administration and stock rotation. This is especially likely if reserves are held in the interior countries.

The gains from regional integration of a financial facility or of grain reserves are indicated in Table 22 by calculating the 95 percent probabilities for food import assistance, net export assistance, and for storage losses. The calculation is exact for the two financial facilities: it shows the amounts of foreign exchange necessary to cover the region's total demand for food import assistance or for net export assistance in 95 of 100 years if there were a common regional fund operating either of the insurance facilities. The calculation can only suggest total grain reserves, because no regional grain reserve is simulated. It does, however, suggest the size of the gains from regional reserves if such reserves do not increase transport or administration costs.

A regional fund for food import assistance or for net export assistance would have to hold substantially smaller amounts of money to cover 95 percent of simulated shortfalls than would seven national funds operating independently. A regional grain reserve—if it did not incur increased costs of transport and administration and if trade were liberal within the reserve area—would also provide some savings. It is much more likely that the insurance funds could realize these savings because such funds would operate by costless transfer of money, whereas the grain reserves would have to effect costly physical transfers of grain.

Reserves and the Vulnerable Populations

The principal vulnerable populations are the nomadic and seminomadic herders of the region's north, and the relatively small urban populations. The herders were most severely affected by the last drought: they suffered real income losses, both from the loss of their livestock and from increases in grain prices. They will suffer such losses again in shortfall years because livestock produc-

[42] See FAO, *National and Regional Stocks*, Summary.

Table 22—Indicative savings from regional over individual country insurance funds and grain reserves

	Savings		Maximum Savings Given 95 Percent Confidence Interval	
	Mean	Standard Deviation	Any Five-Year Period[a]	Sum of All Five-Year Periods
	(U.S. $ million)			
Grain reserves[b]	21.6	6.8	34.9	42.2
Food import assistance	182.4	90.2	358.5	459.0
Net export assistance	168.1	79.5	323.8	484.5

Note: The demand elasticity is −0.2. The figures given are 1979 present values.

[a] For any five-year period there is a 95 percent probability that the value of any of the three mean savings will be less than the values shown in this column.

[b] Grain reserves are equal to roughly 5 percent of 1977 trend consumption in each country.

tion is positively correlated with grain production. Whereas grain production has a stabilizing mechanism, in that prices are inversely related to output, that mechanism operates less strongly in livestock markets and its reverse may at times occur. There is, for example, evidence from Niger that livestock prices fall in droughts because herders sell malnourished animals. Because grain prices are highest in these periods, the herders' real income—livestock prices divided by grain prices—falls.[43]

It is likely that planned reserves in the region could meet most of the needs of the vulnerable groups, even in years of the greatest production shortfalls. Stock releases would have to be concessional in many years—further increasing the reserve agency's losses and reducing the amounts of grain available to other groups. But it is probably true that with the region's current infrastructure, there is no other way to ensure adequate nutrition among the vulnerable groups, especially among the nomads, given their direct real income losses.

Since farm populations may have some private reserves, they would not receive part of the reserves released in most years. The evidence that farm families suffered less malnutrition during the 1971-73 drought than did herders[44] suggests again that stocks should be located in the northern Sahel and that herders should have first claim on them. Farm populations have greater risk when production shortfalls occur consecutively, thus preventing reconstitution of farm stocks; in such years a program to survey on-farm stocks would be a useful part of an early warning system.

It is in the most isolated areas that the worst shortfalls occur because these areas are generally used to produce livestock; thus grain demand usually exceeds supply. This suggests that stock releases might be ordered in every shortfall year and in every area where demand exceeds supply. It is obvious that not all shortfalls lead to famine and it should be obvious that not every region can be be self-sufficient in cereal consumption. Stock releases without reference to normal market prices and supplies could seriously depress incentives to produce cereals by depriving farmers of markets and could seriously inflate incentives to produce livestock by subsidizing cereal consumption.

Conclusions

The proposed national reserves (roughly 5 percent of consumption in most countries) can provide food security at acceptable

[43] See Claude Arditi, "Economie et Politiques Céréalières au Sahel," *Presence Africaine*, no. 113, 1980, pp. 77-95; and Sutter, "Social Analysis."

[44] See Thierry Brun, "Manifestations Nutritionelles et Medicales de la Famine," in Jean Copans, ed., *Sécheresses et Famines*, and Theodore J. Kloth, "Sahel Nutrition Survey," Center for Disease Control, Atlanta, Ga., 1974.

costs, but only if they are complemented by foreign exchange assistance. Such assistance has several advantages over grain reserves. It may soon be provided for as part of the IMF's compensatory finance programs; it would allow recipients to purchase the grain qualities they want; and it would not produce the domestic price distortions caused by grain reserves, distortions that might incur costs from forgone export crops.

None of these policies can be effective unless two measures are taken. The recipient countries must assure that reserves reach the segment of the population that faces the greatest risk, principally the herders of the northern fringe of the region. Unless special measures are adopted this group will suffer the worst losses whenever there is a drought. For example, when subsidized reserves are put on sale, the herders should have first claim.

The donors must take steps to reduce the uncertainty brought about by previous policies. One strong political argument for local reserves is that there is little assurance that food aid or foreign exchange assistance will arrive in time to prevent severe hardships. The donor countries could easily arrange measures to approve payment of foreign exchange assistance or food aid contracts in advance to alleviate uncertainty about availability in time of need. In this way, the costly burden of maintaining excessive grain reserves in the countries of the Sahel would be eliminated.

In the choice between increasing grain reserves and instituting compensatory financing, there is the immediate risk that reserves will be chosen because they are tangible. They do, after all, guarantee food security to privileged segments of the population, and they are visible symbols of donor generosity and official enterprise for the public welfare. But reserves are an expensive means to do what is needed and their costs can only rise. If such reserves fail to protect vulnerable elements of the population, it will probably be said that reserves are too small. With such an emphasis on grain reserves, can the source of the failure be misidentified as insufficient reserves, when the true sources would be poor transport, slow communications, and restrictive trade policies?

APPENDIX 1

ANALYSIS OF RAINFALL DISTRIBUTION

A basic question in the analysis of grain markets is the serial independence of production. If deviations from trend production are positively correlated, then one can expect series of like-signed deviations to occur more often than if such deviations were uncorrelated. If there are frequent runs of like-signed deviations then there would presumably be runs of market prices in the opposite direction.

To test the hypothesis of serial independence in grain production, the Durbin-Watson test (D-W) was applied to the production data series. Those tests are unsatisfactory, however, because the series is short (less than 20 years) and the data are of low quality. To have a better test of the hypothesis of serial independence, regional rainfall data were tested. This is an acceptable test because crop yields depend on rainfall and because there are longer data series of higher quality for rainfall than for production. Data provided by the U.S. National Climatic Center were analyzed to test the distribution of rainfall for normality, time trend, and serial correlation. Sixty-two stations were available, and all countries were represented by at least one station.

The coefficient of skewness was used as the test for normality.[45] Table 23 shows results of the skew test. Only 18 stations showed statistically significant skews, of which 17 were positive. The unskewed stations were assumed to have approximately normal distributions and were accepted for time-series analysis using the D-W statistic. The skewed stations were assumed to have abnormal distributions and two nonparametric tests were used to analyze their serial correlation.[46]

Regional rainfall demonstrates the well-known south to north decreasing pattern in which mean rainfall and the coefficient of variation, or the standard deviation divided by the mean, are negatively correlated.[47] The skewed stations were grouped into 12 cells by latitude (stations below 10 degrees north were placed in one cell and stations above 20 degrees north were placed in another cell) and a chi-square test of the incidence of skewed stations was done. This showed a value of 15.4754, for which (with 11 degrees of freedom) the probability of a higher value is roughly 17 percent. There is some evidence, therefore, that the more arid regions have more skewed rainfall.[48]

Data from the normal stations were transformed into logs for the analysis of the time series. All but 3 of the 43 normal stations showed negative trends, and 28 of

[45] This test is discussed in G. W. Snedecor and William Cochran, *Statistical Methods*, 6th ed. (Ames, Iowa: Iowa State University, 1967), pp. 86-87, 552. For an application to the problem of field crop yields, see Clifton B. Luttrell and R. Alton Gilbert, "Crop Yields: Random, Cyclical, or Bunchy?" *American Journal of Agricultural Economics* 58 (August 1976): 521-531.

[46] The nonparametric tests were the Wald-Wolfowitz runs test and the Wallis-Moore phase test. For a description of the former test, see Richard H. Day, "Probability Distributions of Field Crop Yields," *Journal of Farm Economics* 47 (August 1965): 713-741; for the latter, see Day, "Probability Distributions," and W. Allen Wallis and Geoffrey H. Moore, "A Significance Test for Time Series Analysis," *Journal of the American Statistical Association*, 1941, pp. 401-409.

[47] The correlation coefficient between annual mean rainfall and its standard deviation is 0.6764, which is significantly different from 0 at the 1 percent level. This is consistent with the findings of J. Cochème and P. Franquin in *A Study of the Agroclimatology of the Semiarid Area South of the Sahara in West Africa*, technical report prepared for the FAO/UNESCO/WMO Interagency Project on Agroclimatology (Rome: FAO, 1967), p. 49: "It can be seen that. . .variability increases with aridity from south to north."

[48] Note that Cochème and Franquin conclude otherwise ". . .a quarter of the skewness values are negative and. . .skewness does not markedly increase with aridity" (Cochème and Franklin, *A Study of Agroclimatology*, p. 50.) It is difficult to evaluate Cochème and Franquin's findings about skewness for two reasons. First their sample is based on an earlier period (roughly 1931-60). Therefore, it includes the 1940s, which seems to have been a fairly rainy period. Second, they use as their indicator the statistic $(x - m)/x$, where x is the mean rainfall and m is the median of the time series. The probability distribution of this statistic is not given in their analysis and no estimate of its significance level is possible. Also, if there is a trend in the series, then the simple mean x is not the correct indicator of central tendency.

Table 23—Results of skew tests and nonparametric tests for rainfall distribution

Station Name	Skew	Wald-Wolfowitz	Wallis-Moore
Niger			
Bilma	0.802	−0.835	1.145
Agadez	0.481	0.000	1.697
Tillabery	−0.053	−0.841	0.833
Tahoua	−0.626	−0.400	0.514
Niamey-Aelo	0.486	2.367	5.213
Birnin-Konni	0.723	−1.601	3.499
Maradi	−0.334	−1.111	3.647
Finder	0.546	−2.706	0.851
Maine-Soroa	0.226	−0.663	1.438
Mali			
Tessalit	0.684	0.400	0.305
Tombouctou	1.278	−0.801	5.127
Gao	0.467	0.000	3.106
Nioro du Sahel	0.510	−3.203	2.529
Hombori	0.205	−1.601	2.158
Menaka	0.406	−3.203	19.452
Kayes	0.061	−2.029	2.290
Mopti	0.969	−2.029	7.385
Segou	−0.294	−1.601	0.460
San	−0.091	−0.801	2.443
Kenieba	0.411	0.801	2.158
Bamako	0.114	0.338	3.663
Koutiala	0.670	0.000	5.126
Bougouni	0.636	−2.402	0.305
Mauritania			
F'Derik	1.748	1.201	6.333
Nouadhibou	2.291	−1.353	0.660
Atar	0.717	−1.691	2.072
Akjoujt	0.000	−1.311	0.122
Nouakchott	0.495	−0.338	0.039
Tidjikja	1.186	−2.402	2.768
Boutilimit	1.779	−0.400	2.792
Re'so	−0.019	0.040	5.729
Nema	3.308	−2.029	1.161
Kiffa	−0.037	−0.835	2.158
Senegal			
Saint-Louis	0.205	−0.801	0.460
Podur	1.750	−0.801	1.510
Linguere	−0.210	−2.402	0.206
Matam	0.088	−0.801	0.642
Dakai-Yoff	−0.055	0.000	0.642
Diourbel	−0.287	−1.601	2.428
Kaolack	0.160	−1.601	0.614
Tambacounda	0.323	−1.015	1.202
Zinguinchor	−0.258	−1.201	0.642
Kolda	1.511	−1.601	0.614
Gambia			
Bathhurst-Yundum	0.389	−2.006	0.245
Chad			
N'Djamena	0.561	0.000	2.063
Mao	0.276	−1.046	1.384
Bousso	0.526	−1.201	0.642
Moundou	0.911	0.338	0.101
Pala	1.666	0.000	2.936
Sarha	0.159	−0.676	0.008
Ati	−0.124	−2.002	0.514
Faya-Largeau	2.238	0.520	1.577
Am-Timan	0.337	−0.801	3.590
Abeche	1.098	−1.691	2.086
Mongo	1.322	−0.801	1.137
Upper Volta			
Dori	−0.135	−1.601	0.271
Ouahiqouya	0.126	−1.601	0.403
Ouaqadouqou	0.129	1.353	0.008
Fada N'Gourma	0.182	−1.601	0.266
Bobo Dioulasso	0.249	0.000	0.984
Boromo	−0.843	0.000	2.063

them had trend time elasticities significantly different from zero. The absolute values of the elasticities varied from 0.0058 to 0.558 among the group that differed statistically from zero. A chi-square test of the relation between the latitudes of the normal stations and the significance of their trend regression coefficients showed no relation between the two (chi-square is 3.2751 for 11 degrees of freedom).

Stations with normal distributions were then tested for serial correlation using the D-W statistic. Of those 43 stations, only 1 has a significant D-W statistic and only 3 fall in the indeterminate area in which the hypothesis that the serial correlation coefficient (p) is equal to zero can be neither accepted nor rejected.[49]

Partial analysis of the 43 normal stations shows, then, that there is no systematic tendency for rainfall in the average year to be greater or less than in the most frequent year, and no systematic tendency for runs of years with rainfall above or below the average to occur. It is further shown that although northern stations have more variable rainfall, they have a strong but not strictly significant tendency to have abnormally distributed rainfall. Latitude does not affect the trends found in the regression analysis of rainfall.

The Wald-Wolfowitz (W-W) and Wallis-Moore (W-M) tests were used to analyze the time series of the stations that had significantly skewed distributions.[50] Table 23 gives results of the trend tests. The W-W test has a statistic distributed roughly as Z; its application to the 18 skewed stations shows only 5 stations with Z values significantly negative at levels slightly above 95 percent, and the rest of the tested stations showed no significant tendency to have runs of years with rainfall greater or less than the median value of the time series. Four of the five significant stations are from areas of median rainfall less than 427 millimeters which are clearly in marginal agricultural zones. The fifth station in this class is at Mopti, Mali, which is on the border of the marginal rainfall zone.

Results of the W-M tests confirm those of the W-W test, showing only three stations with significant cyclical behavior. One of those stations shows more phases of length one than expected.[51] This is ideal for operating a buffer stock. One of the other two stations showed twice as many phases of length two as expected. It does not seem that this isolated event could seriously affect buffer stock operations. The third station showed more phases of length greater than two years than expected. It is therefore the only one that could be expected to disrupt storage programs.

A review of some of the available rainfall data and application of commonly used statistical tests shows that: more than two thirds of the rainfall stations had approximately normal distributions during the period 1951-76, with some stations going back to 1941; of the stations with normally distributed rainfall, there is almost no evidence of serial correlations of the deviations from trend using the standard D-W statistic; of the stations with skewed rainfall, 17 of 18 had positive skews; of those skewed stations, only 7 appear to have any significant evidence of serial correlation using nonparametric tests; and of the stations showing significant serial correlation with the W-M test (which is more appropriate to the problem of relatively brief cyclical phases in time series), only two have patterns that might interfere with buffer stock operations. It is reasonable to conclude, therefore, that there is no strong statistical evidence of brief runs or phases in the distribution of regional rainfall.

There are several qualifications to this analysis. The first is that it uses a brief period (in most cases, only 26 years). The brevity of the period is compounded because in roughly one-third of the stations complete years were missing from the series and had to be replaced with average values. This, naturally, reduces the variance in the estimates and reduces the estimate of the skew coefficients.

Second, the analysis used no information on the probability distribution of other variables affecting crop yields or on the covariance of rainfall and other such variables. This amounts to an admission that no model of crop yields was estimated. It may be that the estimation of the coefficients of such a

[49] See Ronald J. Wonnacott and Thomas A. Wonnacott, *Econometrics* (New York: Wiley, 1970), pp. 427-428.

[50] The tests are discussed in Day, "Probability Distributions" and in Wallis and Moore, "A Significance Test."

[51] See Luttrell and Gilbert, "Crop Yields" for a discussion of this problem.

model would show the serial correlation that was not found in this analysis.

Third, while most of the analysis is of the implicit relation between rainfall and crop yields and shows that this rainfall in agricultural areas is roughly normal without serial correlation, results from the northernmost zones of the region are quite different. These areas show strong evidence of positively skewed distributions but little evidence of serial correlation, implying that livestock producers can expect the normal year to be less productive than the average year because of the frequency of extraordinarily wet years. One can therefore expect that the ratio of livestock prices to grain prices (the terms of trade between herders and farmers) will be skewed, and that this will usually be to the herders' advantage.[52]

These results imply several elements of the simulation analysis of regional production. If one assumes that crop yields depend largely on rainfall (and production on yields), then it follows that the distribution of yields should approximate the distribution of rainfall. This implies, first, that the distribution of yields should be approximately normal, and second, that yield in one year is not a function of yield in the preceding year or years.

If the distribution of yields in the region is normal and shows no serial correlation, it then follows that the distribution of Sahel grain prices should also be distributed approximately normally around its trend, at least until some new technology intervenes to disturb that trend. Furthermore, if production is not serially correlated, then one cannot expect systematic runs on grain reserves, whether as several years of excess supplies (with depressed prices necessitating stock purchases) or as several years of deficit supplies (with stock sales to reduce inflated prices). Finally, if the spatial pattern of production in the region is approximately normal—that is, if all areas have normally distributed production without serial correlation—then the normal patterns of surpluses and deficits can be expected without systematic disruption caused by a skewed distribution of production in one part of the region.

[52] The herders will suffer unless they are able to save their gains from extraordinarily good years and thus maintain average purchases of grain.

APPENDIX 2

STORAGE COSTS

This appendix gives a brief review of some cost estimates for grain storage in the Sahel extracted from mission reports and various studies made since the 1968 to 1974 drought. The authors of these studies usually attempted to improve modern stores of grain owned by state marketing agencies and paid little attention to farm storage, which has always been the most important element of the storage network. Existing studies are, with few exceptions, based on brief visits to the region and not on cost-route surveys.[53]

Table 24 presents a compilation of construction costs in 1978 dollars for building grain reserves. Exchange rates in the original estimates are shown with the table, and a 10 percent annual rate of inflation has been assumed to bring the estimates to 1978 values. Table 25 shows some estimates of economies of scale in stock construction derived by the author from published sources. They are significant in some instances, but one must remember that they are based on cost projections, not on construction records. Exploitation of such economies, if they do exist, is limited to areas where there is sufficient turnover to justify larger stocks, and this probably excludes remoter areas.

In Table 26, estimates of the operating costs of modern stores are given. These data are particularly unreliable because experience with modern methods of stock protection is short.[54] If interest is excluded, the principal operating cost is the cost of buying sacks. This cost could be eliminated if bulk storage were used for reserves, but adoption of bulk techniques is hampered by the supply of power and by use of sacks in all aspects of primary marketing. Incorporation of bulk reserve stocks into the system would clearly make it more costly to rotate the reserves.

In spite of limited evidence, some things are plain. First, interest is the principal cost in the total cost of reserve storage. From this, it follows that concessional aid to build stores can only contribute a small part to a food security scheme unless it includes financing of recurrent costs. Second, there is a high return to modern stock protection.[55] Recognition of the fact is obscured by the poor record of marketing agencies, but that record is caused by resource limitations and should be improved. Third, exploitation of economies of scale is possible, but limited, whereas losses from low utilization of capacity are large. Fourth, the penalty on storage in remote areas, such as Gao in Mali or Agadez in Niger, arises from increased construction and maintenance costs.[56] Finally, so little is known about commercial storage that its existence cannot be accounted for in any meaningful way in modeling work.

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[53] Exceptions are L. A. W. Hayward, "Preliminary Comparison of Different Grain Storage Methods in the Sahel with Special Reference to Niger," Niamey, 1978 (mimeographed); Hans Guggenheim, "Of Millet, Mice and Men: Traditional and Invisible Technology Solutions to Post-Harvest Losses in Mali," in *World Food Pest Losses and the Environment* ed. David Pimental (Boulder, Colo.: Westview Press, 1978), pp. 109-162; G. Yaciuk and A. Yaciuk, *Résultats de l'Enquête sur la Technologie Post-Récolte en Milieu Paysan* (Dakar: Centre National de Recherche Agronomique/Institut Sénégalais de Recherche Agronomique, 1977); and FAO, *Evaluation Technique*. The reader interested in a review of the subject is referred to the FAO study cited immediately above and to CILSS, Club of the Sahel and Arup Partners, *Etude sur le Stockage*.

[54] FAO is undertaking a one-year analysis of the recurrent costs of modern storage in Mali, Niger, and Chad as part of its *Evaluation Technique* study.

[55] See Hayward, "Preliminary Comparison," for a succinct discussion.

[56] FAO, *Evaluation Technique*, p. 44, notes that construction costs are 20 percent greater in the south of Niger than those in Niamey or Zinder; it also observes that construction costs in the north of Niger can be as much as 40 percent greater.

Table 24—Estimates of construction costs of a grain reserve

Source	Type of Facility	Average Capacity	Maximum Capacity	Service Life	Exchange Rate	Average Annual Cost	Minimum Annual Cost
		(metric tons)		(years)	(CFAF/$)	(1978 U.S. $/metric ton)	
AID[a]	Bag warehouse	1,858	1,000	20	250	5.58	4.79
ARUP[b]	Bag warehouse	1,000	n.a.	20	212.5	5.92	n.a.
FAO[c]	Bag warehouse	1,750	n.a.	40	210	14.04	n.a.
FAO[d]							
Mali	Bag warehouse	1,200	1,900	20	220	8.69	5.49
Mauritania	Bag warehouse	500	640	20	220	16.99	13.27
Upper Volta	Bag warehouse	1,800	2,800	20	220	4.96	3.19
Mali	Bag warehouse	2,700	3,700	25	220	4.15	3.03
Niger	Bag warehouse	350	500	25	220	5.59	3.91
Mauritania	Riedel silo	500	550	5	220	7.72	7.02
Upper Volta	Riedel silo	500	550	5	220	8.18	7.44
Niger	Riedel silo	500	550	5	220	5.93	5.39
FAO[e]	Bag warehouse	1,500	n.a.	20	214.32[f]	4.05	n.a.
Orstom[g]	n.a.	n.a.	n.a.	n.a.	220	n.a.	n.a.
Pinckney[h]	Silos	1,500	n.a.	5	245	12.[illegible]9	n.a.
Pinckney[h]	Bulk	1,500	n.a.	25	245	4.57	n.a.
Wilcock[i]	Silo	n.a.	n.a.	40	250	5.07	n.a.
Wilcock[i]	Warehouse	n.a.	n.a.	40	250	3.59	n.a.
World Bank[j]	Bag warehouse	1,000	n.a.	25	225	5.91	n.a.

Note: Average capacity is that shown in the original estimate and is the amount most likely to be stored in a given facility. Maximum capacity is that which could be stored if the facility were used for a reserve stock, in which case bags could be piled higher and aisles could be made narrower or eliminated altogether. Service lives and exchange rates are those shown in the originals except where noted otherwise. Estimates from before 1978 have been converted to 1978 dollars with a 10 percent rate of inflation.

[a] U.S. Agency for International Development, *Project Paper Senegal Grain Storage* (Dakar: AID, 1977), Annex B5, pp. 1-2. The estimates are for Senegal in 1977.

[b] Comité Inter-Etats de Lutte Contre la Sécheresse au Sahel, Club of the Sahel, and Arup Partners, *Etude sur le Stockage des Céréales dans les Pays du Sahel*, 4 vols. (Paris: CILSS Club of the Sahel, 1978), 1: 86, 90, 128-130. The estimates are for the Gambia and Senegal in 1978.

[c] Food and Agriculture Organization of the United Nations (FAO), *Etude de Préfactibilité sur les Stocks de Securité d'Urgence aux Niveaux National et Régional au Sahel* (Rome: FAO, 1979), Annex 12, pp. 1-2. The estimates are for the Sahel. The original shows a capacity range of 1,500-2,000 metric tons; 1,750 is in the middle of the range.

[d] FAO, *Evaluation Technique des Moyens de Stockage des Réserves de Grain au Sahel. Premiere Phase* (Rome: FAO, 1979), pp. 3-8, 16-22, 34-37, 39-44, and 65-56. The estimates are for 1978.

[e] FAO, *Etude Prospective pour le Développement Agricole des Pays de la Zone Sahélienne. 1975-1990*, 3 vols. (Rome: FAO, 1976), p. 23. The estimates are for Niger in 1975.

[f] The rate used to convert Communauté Francais Africaine francs (CFAF) to dollars is from series AF of International Monetary Fund, *International Financial Statistics 1977 Annual Supplement—Annual Data 1952-1976* 30 (May 1977). The rate used is for Niger in 1975.

[g] Société Centrale pour l'Equipement de Territoire International and Société des Etudes pour le Développement Economique et Sociale, *Essai de Définition d'Une Strategie Anti-Sécheresse dans le Sahel de l'Afrique de l'Ouest*, 2 vols. (Paris: SCET International-SEDES, 1975), 1: 251, 2: Annex 12, Table v30. The estimates are for the Sahel. This study does not describe the type of facility, capacity ranges, or service lives and gives no basis for its assumption that investment costs are 15,000 CFAF per metric ton.

[h] Annette M. Pinckney, *An Analysis of Grain Storage in Three Interior Sahel Countries* (Ann Arbor, Mich.: University of Michigan, Center for Research on Economic Development, n.d.), pp. 68-69. The estimates are based on data from Upper Volta.

[i] David C. Wilcock, *The Political Economy of Grain Marketing and Storage in the Sahel*, Michigan State University, Department of Agricultural Economics, Working Paper No. 24 (East Lansing, Mich.: Michigan State University, 1978), Appendix B. The estimates are for Niger.

[j] International Bank for Reconstruction and Development, *Special Sector Survey: Emergency Grain Reserves for the Sahelian Countries* (Washington, D.C.: IBRD, 1975), pp. 22-23.

Table 25—Estimation of economies of scale in constructing a grain reserve

Source	Type of Facility	Average Scale	Highest Scale	Average Cost	Lowest Cost	Percentage Difference Between Lowest Cost and Average Cost
		(metric tons)		(1978 U.S. $/metric ton)		
AID[a]	Bag warehouse	1,000	2,000	4.79	4.12	−14.0
Arup[b]	Bag warehouse	5,000	10,000	16.50	11.25	−31.8
FAO[c]	Unknown	1,300	1,800	4.26	4.67	+9.7
Hayward[d]	Bag warehouse	500	1,500	2.70	1.80	−33.3
Wilcock[e]	Bag warehouse	600	1,000	2.87	2.70	−5.9
Wilcock[e]	Bag warehouse	250	1,000	6.40	4.67	−27.0

Note: The reader is reminded that these comparisons are not between costs in the same facility at different proportions of capacity used, but between different facilities of different scales with the same proportion of capacity used.

[a] U.S. Agency for International Development, *Project Paper Senegal Grain Storage* (Dakar: AID, 1977). The estimates are for Senegal.

[b] Comité Inter-Etats de Lutte Contre la Sécheresse au Sahel, Club of the Sahel, and Arup Partners, *Etude sur le Stockage des Céréales dans les Pays du Sahel*, 4 vols. (Paris: CILSS/Club of the Sahel, 1978). The estimates are for Senegal and the Gambia.

[c] Food and Agriculture Organization of the United Nations, *Evaluation Technique des Moyens de Stockage des Réserves de Grain au Sahel: Premiere Phase* (Rome: FAO, 1979). The estimates are for Chad. The type of warehouse referred to is not known, but it is probably a bag warehouse.

[d] L. A. W. Hayward, "Preliminary Comparison of Different Grain Storage Methods in the Sahel, with Special Reference to Niger," Niamey, 1978. (Mimeographed.) The estimates are for warehouses in Niger built by the U.S. Agency for International Development in 1974.

[e] David C. Wilcock, *The Political Economy of Grain Marketing and Storage in the Sahel*. Michigan State University, Department of Agricultural Economics, Working Paper No. 24 (East Lansing, Mich.: Michigan State University, 1978). Wilcock cites estimates for Chad in 1974 and 1975.

Table 26—Estimates of costs of operating a grain reserve

Source	Type of Facility	Grain Price	Sacks	Pest Control	Interest	Losses	Other	Exchange Rate	Annual Variable Costs
		(CFAF/metric ton)						(CFAF/U.S. $)	(1978 U.S. $/metric ton)
AID[a]	Bag warehouse	35,000	2,100[b]	375	2,275[c]	1,556[d]	777[e]	250	31.17
ARUP[f]	Bag warehouse	35,000	2,100[b]	109	2,275	1,617[g]	5,131[h]	212.5	52.86
FAO[i]	Bag warehouse	60,000	1,000[j]	750	0	1,800[k]	880[l]	210	21.10
FAO[m]	Bulk silo	60,000	0	345	0	600[n]	1,327[o]	210	10.82
Hayward[p]	Buffer stock; Bag warehouse	40,000[q]	n.a.	766[r]	n.a.	1,400[s]	n.a.	220	10.31
Hayward[p]	Reserve stock; Bag warehouse or silo	40,000	n.a.	150[r]	n.a.	200[s]	n.a.	220	1.59
SONED[t]	Bag warehouse	n.a.	...	...	...	...	2,946[u]	220	14.73
Pinckney[v]	Bag warehouse and bulk silo	n.a.	...	...	...	...	10,667[w]	245	47.89
Wilcock[x]	Silo	30,000	85	0	2,400[y]	30[z]	1,034[aa]	250	18.89
	Bag warehouse	30,000	260	375	2,400[y]	300[z]	946[aa]	250	22.79
World Bank[bb]	Bag warehouse	35,000	550[cc]	250	0	875[dd]	1,475	225	18.63

Notes: Millet and sorghum are assumed to be the grains stored. Cost estimates for interest and losses are based on 100 percent capacity utilization. Exchange rates are those shown in the original sources. Estimates before 1978 were converted to 1978 dollars with a 10 percent annual rate of inflation assumed. Where n.a. appears, the figure was not available.

[a] U.S. Agency for International Development, *Project Paper Senegal Grain Storage* (Dakar: AID, 1977), Annex B5, pp. 2-6.

[b] This assumes that 10 sacks hold 1 metric ton, that each sack costs CFAF 620, and that each sack lasts three years.

[c] This is 6.5 percent of the market price. It excludes the costs of marketing the grain after it is produced and before it is stored.

[d] This is 4 percent of the purchase price plus the costs of loading, transport, sacks, storage, and fumigation.

[e] This includes the costs of handling and warehouse maintenance.

[f] Comité Inter-Etats de Lutte Contre la Sécheresse au Sahel, Club of the Sahel, Arup Partners, *Etude sur le Stockage des Céréales dans les Pays du Sahel* 4 vols. (Paris: CILSS/Club of the Sahel, 1978), 1:86-89.

[g] This is 4 percent of the average volume.

[h] This is the cost of maintenance.

[i] Food and Agriculture Organization of the United Nations, *Etude de Préfactibilité sur les Stocks de Securité d'Urgence aux Niveaux National et Regional au Sahel* (Rome: FAO, 1979), Annexes 11 and 12.

[i] There is no explanatory note in the original.

[k] This is 3 percent of the purchase price, which was CFAF 60,000 per metric ton.

[l] This includes the costs of maintenance, management, and utilities.

[m] FAO, *Etude de Préfactibilité*, Annexes 11 and 12.

[n] This is 1 percent of the purchase price, which was CFAF 60,000 per metric ton.

[o] This includes personnel and holding costs.

[p] L. A. W. Hayward, "Preliminary Comparison of Different Grain Storage Methods in the Sahel, with Special Reference to Niger," Niamey, 1978, pp. 6-10, 12. (Mimeographed.)

[q] This is the 1977-78 producer price paid for millet in Niger.

[r] Buffer stocks are treated four times each year; reserve stocks are only treated once.

[s] This is 3.5 percent of the buffer stock and 0.5 percent of the reserve stocks.

[t] Société Nationale des Etudes de Développement, *Etude sur la Commercialization et le Stockage des Céréales au Senegal* 2 vols. (Dakar: SONED, 1977). These estimates are for a 33,000 metric ton facility.

[u] This includes the costs of maintenance, management, pest control, sack replacement, and utilities. No interest charge is made on stored grain, and losses are calculated only from storage costs, not including the purchase price of the grain.

[v] Annette M. Pinckney, *An Analysis of Grain Storage in Three Interior Sahel Countries* (Ann Arbor, Mich.: University of Michigan, Center for Research on Economic Development, n.d.), pp. 68-69. The estimates are for 9,000 metric tons (7,500 in warehouses, 1,500 in silos) in Upper Volta.

[w] This includes the costs of stock protection, transport, administration, and training. The estimates include some capital costs.

[x] Davis C. Wilcock, *The Political Economy of Grain Marketing and Storage in the Sahel* Michigan State University, Department of Agricultural Economics, Working Paper No. 24 (East Lansing, Mich.: Michigan State University, 1978), Appendix B.

[y] This is 8 percent interest on the price of the grain.

[z] This is 0.1 percent of the price of grain in silos; 1.0 percent of the price of grain in warehouses.

[aa] This includes the costs of handling, management, personnel, and energy.

[bb] International Bank for Reconstruction and Development, *Special Sector Survey: Emergency Grain Reserves for the Sahelian Countries* (Washington, D.C.: IBRD, 1975), pp. 23-24.

[cc] This assumes that 10 sacks hold 1 metric ton, that each sack lasts 2 years, and that each sack costs CFAF 11.

[dd] This is 2.5 percent of the price of the grain.

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John McIntire conducted the research for this report at IFPRI under the auspices of the U.S. Department of Agriculture.

At present he serves as a principal economist with the International Crops Research Institute for the Semi-Arid Tropics (ICRISAT) in West Africa.