Food Markets and Food Security in West Africa

Clemens Lutz (ed.)

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Preface

The papers presented in this CDS Research Report centre around three PhD studies in the CDS research theme groups on Food Security and Food Markets in West Africa. They discuss problems of food security and food markets in Burkina Faso. The studies were the subject of two international workshops at the University of Groningen, one on October 25, 2000 and one on January 30, 2002. This Research Report publishes the key papers of these two workshops.

Boubie Bassolet's thesis is entitled "Libéralisation du Marché Céréalier au Burkina Faso", he is currently assistant professor at the UFR/SEG of the University of Ouagadougou in Burkina Faso. Arno Maatman's book is entitled "Si le fleuve se tord, que le crocodile se torde; une analyse des systèmes agraires de la region Nord-Ouest du Burkina Faso à l'aide des modèles de programmation mathématique". He is currently head of the Input Accessibility Programme of the International Institute for Soil Fertility Management in Africa (IFDC) in Togo. Finally, Arjan Ruijs' study is entitled "Cereal Trade in Developing Countries: A Stochastic Equilibrium Analysis of Market Liberalisation and Institutional Change in Burkina Faso". He is currently assistant professor at Wageningen Agricultural University in the Netherlands. The papers of Bassolet, Maatman and Ruijs in this CDS Research Report summarise the major findings of their studies.

Several academics participated in the seminars, after being part of the reading committees for the PhD theses. This report includes the papers of Prof. Erik Thorbecke of Cornell University (USA), Prof. John Sanders of Purdue University (USA), Dr. Clemens Lutz, associate professor at the Faculty of Management and Organization, University of Groningen, and Dr. Peter Hazell, senior research fellow at the International Food Policy Research Institute (USA).

This book gives a nice overview of the present research activities of the CDS research theme group on Food Security and Food Markets. The authors apply advanced quantitative techniques, while showing at the same time the relevance of the research results for development policies in Burkina Faso as well as elsewhere.

Clemens Lutz
Editor

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Poverty and Malnutrition in Sub-Saharan Africa

**Christian Morrisson, Erik Thorbecke,
H. Guilmeau and C. Linskens**

1.Introduction

Sub-Saharan Africa, along with the Indian subcontinent, is one of the two regions of the world where poverty is most extensive and the only region where it continues to worsen not only absolutely but relatively as well. The main purpose of this paper is to explore the interrelationship between absolute poverty and malnutrition. The availability of anthropometric data for 19 countries accounting for 70% of the region's population (excluding South Africa) from Demographic and Health Surveys (DHS) makes it possible to compare and contrast estimates of absolute poverty for these countries (based on income and expenditure surveys or living standard measurement surveys) with estimates of malnutrition derived from DHS. In a more general sense, the availability of DHS has led to a renewal of interest in analyzing malnutrition in the Third World (Smith and Haddad, 2000). There are good reasons for using nutritional indicators as an important dimension and reflection of absolute poverty.

First, the use of nutrition as a measure of poverty is consistent with Amartya Sen's (1985, 1987) notion of defining poverty based on capabilities and functionings. These concepts reflect deprivation better than moneymetric measures based on household income or expenditures. Secondly, a major advantage of nutritional indicators is that they reflect an actual individual outcome (such as a given weight for age score) rather than a mean, which would be the case for household total income or expenditures. If the household has a total income that, in principle, would be sufficient to yield all of its members with a diet sufficient to provide the necessary nutrients to guarantee a healthy life, the actual allocation of that income may be such as to deprive some, or all, of its members from the required calories and nutrients for good health. Income can be thought of as an input variable, while, a nutritional indicator is clearly an output variable. Thirdly, nutritional indicators measure the status of individuals whereas moneymetric measures are derived from household level observations that have to be converted into individual measures by way of equivalence scales. There is a rich literature on equivalence scales but no general agreement on the best method. The range of equivalence scales goes from per capita to scales based on age and gender-specific caloric requirements. The existence of family economies of scale is another complication that needs to be taken into account before individual consumption estimates of household members can be arrived at. Given how little is known about the intra household food allocation, individual welfare inferences drawn from household level data amount to approximations, at best.

The starting point of this paper is to equate poor health due to malnutrition with poverty. First, we are considering as poor, those households whose children suffer from poor health because their food needs and health care are not met. Clearly, since poverty is highly multidimensional other criteria, such as education, could have been added. Our analysis limits itself to food and health care needed for an individual to be in good health.
This paper consists of the following sections. Section 2 explores the relationship between absolute poverty and average income. Section 3 is devoted to anthropometric data and malnutrition. Section 4 analyzes the interrelationship between malnutrition and poverty. Section 5 compares alternative methods of estimating malnutrition and Section 6 concludes.

2. Relationship between Absolute Poverty and Average Income

The concept of absolute poverty is anchored to nutritional requirements, as is made clear in a recent study by Ravallion (1998). There are two methods of determining a poverty line for a given population. The first method is the so-called Food-Energy-Intake (FEI) approach that estimates the relationship between the value of food consumption (including the imputed value of production for self consumption) and the calories consumed at the household level from survey information. Once this relationship has been estimated empirically a minimal calorie threshold (corresponding to the recommended dietary intake for that population) can be established. For each individual, the working capacity and the maintenance of a healthy life is a function of food consumption and individual characteristics such as age, gender, and occupation. Different age groups and occupations require different levels of energy intake depending on the level of energy expenditure required to perform their various tasks. Hence, the poverty line is defined as the monetary value of the minimal food consumption necessary to maintain good health and function in society.
The FEI approach has been known for a long time (Dandekar and Rath, 1971) and has been used in many countries. Greer and Thorbecke (1986) provide a good illustration of its application to Kenya where the relationship between caloric consumption and the value of food consumption was estimated for six provinces. One advantage of this method is that it reflects the actual behavior of households in a specific setting, given their tastes, preferences and the relative prices, which

they face. Empirical studies agree on the nature of the relationship between caloric consumption and the value of food consumption; the former is an increasing, non-linear (concave) function of the latter[1]. Given the caloric Recommended Dietary Allowance (RDA) for the population under consideration the corresponding value of food consumption is deduced from the function. Since individuals cannot live from bread alone and have other needs than just nutrition, an additional amount has to be added for other basic needs to obtain the overall poverty line rather than just the food poverty line as above. Since budget surveys give both food and non food consumption one can derive the total expenditure corresponding to the poverty line (z) by regressing the value of total expenditures on that of food expenditures.

The second method of deriving the poverty line is the Cost of Basic Needs (CBN) method. Under the CBN approach a bundle of food items meeting an exogenously defined normative nutritional (caloric) requirement is specified. For example, in the case of the World Bank poverty profile of Bangladesh, the food bundle consisted of fixed quantities (expressed in grams) of 11 different food items (Wodon, 1996). The same diet is assumed to be consumed by all households in every region and every socioeconomic group. The CBN diet is essentially a normative diet, which is imposed on all subsets of the population.

A critical principle postulated by the proponents of the CBN method (i.e. Ravallion and Bidani, 1994) in preferring it to the FEI approach is that of "consistency", i.e. a poverty profile is "consistent" when a given standard of living does not depend on which subgroup in the poverty profile the person with that standard of living happens to belong. The contrasting principle mentioned by the authors is that of "specificity", i.e. when the choice of the poverty line reflects "local perceptions of what constitutes poverty" which would be the case with the FEI approach. The important issue here is that both methods are anchored on the food consumption providing adequate nutrition for the fulfillment of a healthy and productive life, and allowing individuals to function in their communities.

[1] Strauss and Thomas (1995, pp. 1893-1908) present an exhaustive picture of this empirical relationship and conclude that this function is increasing and concave up to some level of expenditure where there is no longer any correlation: the consumption of calories is the same whatever the expenditure. If only lowincome families are considered, the elasticity of caloric consumption in relation to expenditure is neither 1, as some suggest, nor close to 0 as others have asserted, but it varies around 0,3-0,5, according to Strauss and Thomas.

Typically national authorities derive the poverty line on the basis of either one of these two methods. The cost of a basket of goods satisfying food requirements grows with GDP per capita for several reasons: such as, changes in the range of goods consumed as income increases, rising prices of basic foodstuffs compared to prices of other goods, increasing proportion of population in urban areas where foodstuffs maybe be more expensive than in rural areas, gradual disappearance of subsistence farming. These factors lead to the concept of a flexible or adjustable absolute poverty line. Thus, from a sample of 48 developing countries (of which 16 are in Sub-Saharan Africa), Ali and Thorbecke (2000) estimated the relationship between mean income μ and the poverty line z derived in these countries based on the best and most comparable studies available. This procedure yielded the following equation (with the absolute values of t statistics given between parentheses):

$$\text{Log } z = \underset{(100.9)}{5.181} + \underset{(18.3)}{0.00158\mu} - \underset{(10.9)}{0.0000003485\mu^2} \qquad (1)$$

$$R^2 = 0.96$$

Table 1. Poverty Line and GDP Per Capita

GDP Per Capita (μ) (in dollars)	Poverty line (z_{AT}) (in dollars)
100	207
200	240
300	276
400	316
500	359
600	404
700	453
800	503
900	556
1000	609
1200	717
1400	820
1600	913
1800	988
2000	1040

Note: according to the relationship of Ali and Thorbecke

For any given mean income we can thus derive the corresponding poverty line (Z_{at}) following the Ali-Thorbecke method as Table 1

shows for the 19 countries in our sample[2]. In order to estimate the percentage of poor in the population we need to know the income distributions of these 19 countries, in addition to their mean incomes. We use the known income distributions for 11 of these countries (Bourguignon and Morrisson, 1998) and assume likely distributions for the other eight countries[3]. Thus, the percentage of poor Po (which in the remainder of the paper refers to the headcount ratio derived according to the Ali-Thorbecke, 2000 procedure), in a country is determined by three factors, the poverty line, Z_{at}, mean income, g, and the prevailing income distribution. Table 2 gives the values of Po for 19 countries derived according to the above procedure[4].

[2] This specification has the advantage that for low-income countries the elasticity of the poverty line with respect to mean income is low, thus, for example, for Tanzania with a mean income of $302 in 1993 the elasticity is 0.39 while for Ghana (with a per capita income of $796) the elasticity approaches the maximum and is equal to 0.82. Table 1 shows the values of the poverty line (z) as a function of mean income (μ). In the poorest countries like Niger z clearly exceeds the average income ($200). The two values are equivalent for W=$280. Subsequently the z/μ ratio falls below unity. Thus for dote d'Ivoire (g. -$660) the ratio amounts to 0.65.

[3] More specifically, we assume that Benin, Burkina Faso, Mali, and Niger have the same income distributions as that of Togo. Likewise we assumed that Nigeria and Tanzania have the same distribution as that of Senegal, that Cameroon's distribution corresponded to that of Cdte d'Ivoire and Rwanda's distribution was equivalent to that of Burundi.

Note that since the DHS that we are subsequently using to derive nutritional indicators were undertaken in different years, we computed the mean per capita income of the five years preceding the year of the survey on the assumption that a child's nutritional status at one point in time is influenced by the evolution of household income in the previous five years. Furthermore, given the staggering variability of mean incomes in SSA countries from year to year we took the average of the above value and per capita income in 1996 to yield μ.

Table 2. Percentage of Poor, Po

Benin	59.95	Namibia	65.70
Burkina Faso	70.45	Niger	70.55
Burundi	76.90	Nigeria	70.50
Cameroon	51.85	Rwanda	69.75
Côte d'Ivoire	53.25	Senegal	57.30
Ghana	59.50	Tanzania	80.00
Kenya	68.15	Togo	62.15
Madagaskar	77.15	Uganda	62.90
Malawi	82.80	Zimbabwe	62.65
Mali	70.70		

Note: according to the method of Ali and Thorbecke

3. Anthropometric Data and Malnutrition

Demographic and Health Surveys cover infants under six years of age and mothers. The anthropometric data that these surveys yield have several recognized advantages. First, as indicated previously, the unit of observation is that of the individual infant or mother, in contrast with income and expenditure survey or Living Standard Measurement (LSMS) household surveys where the unit of observation is the household. Specific information on the nutritional and health status of an individual infant or mother overcomes the need to make (somewhat arbitrary) assumptions regarding the distribution of foodstuffs among household members. Furthermore, it is easier to measure the height or weight of an individual than his or her consumption of calories. The cost of measuring height or weight are small and these measurements can be made without difficulty even in a poor rural area. The indicator of nutritional (health) status used in this paper is a standardized height-for-age of children 5-59 months of age. The height-for-age-score z score (HAz) is an indicator of a child's long-term nutritional (health) status. Children who are "stunted" are those whose past chronic nutritional deprivations leave them shorter than expected for their age and gender cohorts in the reference population. More specifically, the zscore is defined as follows:

$$z-score=\frac{x_i-x_{median}}{\delta_x} \qquad (2)$$

Where x_i is height for child i, x_{median}, is the median height for a healthy wellnourished child from a reference population of the same age and

gender, δ_x is the standard deviation from the mean of the reference population. The percentage of the given population with a z-score that falls two standard deviations below the mean reference population is said to be malnourished. As recommended by the World Health Organization (WHO, 1995), the standard reference population used here is that of the United States National Center for Health Statistics. Studies such as Martorell and Habicht (1986), which found that less than 10% worldwide variance in height is due to differences in genetics or race among children of the same sex under the age of ten, provide a strong rationale for using such a reference population.

The DHS provide information on the height and weight of children under six years old in 19 SSA countries and the Quetelet Index (the weight in kilograms divided by the square of the height in meters) for mothers in 9 SSA countries. For children the height-for-age (HAz) indicator reflects living conditions since birth. For example, a four-year-old child nourished appropriately at the present time can be short because he or she suffered from malnutrition between the ages of 1 and 3. On the other hand, the weight-for-age (WAz) score reflects the current nutritional conditions. It does not distinguish between children that weigh less or are underfed because they are of short stature. The same distinction applies to indicators of mother's health: height is related to past nutrition and care while the Quetelet index expresses current nutritional conditions[5].

Having chosen as the criterion of poverty the appropriate nutrition of children, all families whose children suffer from serious malnutrition (i.e. displaying z scores below two standard deviations of the median of the reference population) will be considered as poor. In Table 3 we present the estimates of the percentages of children affected by malnutrition according to three different indicators, i.e. height-for-age z-score, HAz; weight-for-age z-score, WAz; and the average of the above two indicators. Since the HAz indicator is the best indicator of malnutrition, it will be mostly, but not exclusively, used in the analysis that follows. We denote the three corresponding malnutrition headcount ratios as M_o(HA), M_o(WA), and M_o*, respectively.

[5] However, these indicators can sometime be misleading. Recent, prolonged illness can lead to a person being underweight for several reasons (lack of appetite, intestinal parasites, and diarrhea), even if, in theory, the person consumed a sufficient food ration. Deficiencies of certain specific products (like zinc) can affect height even if sufficient calories are consumed. Finally, a satisfactory weight (between _+ two standard deviations) does not guarantee that an individual is capable of actually performing the necessary physical activity, as the level of activity and energy expenditure may adjust downward to equal energy intake without necessarily affecting individuals' weight

Table 3: Malnutrition Indicators
(% of children below 2 standard deviations of median of reference population, height-for-age-z-scores: HAz and WAz indicators)

Country	Year	Mo(HA)	Mo (WA)	Mo*[a]
Benin	1996	28.8	34	31.4
Burkina Faso	1992	37.1	36.5	36.8
Burundi	1987	50	40.3	45.15
Cameroon	1991	28.7	16.6	22.65
Côte d'Ivoire	1994	28.1	27.5	27.8
Ghana	1988	31.5	32.4	31.95
Kenya	1993	35.5	24.1	29.8
MadagaskarM	1992	58.3	45.2	51.75
alawi	1992	54.3	30.8	42.55
Mali	1995	35.7	47.3	41.5
Namibia	1992	30.7	29.3	30
Niger	1992	44.7	48.7	46.7
Nigeria	1990	46.4	38.8	42.6
Rwanda	1992	52.7	32.1	42.4
Senegal	1992	27.3	25	26.15
Tanzania	1992	46.9	32	39.45
Togo	1988	33.3	27.8	30.55
Uganda	1988	48.1	25.3	36.7
Zimbabwe	1994	24.7	18	21.35

[a] *Mo* is the average of Mo (HA) and Mo (WA)*

An examination of the data in Table 3 suggests the following observations: First, it is not surprising that the Mo(HA) ratio tends to be higher than the corresponding Mo(WA) ratio in the majority of countries since the former reflects the cumulative effects of malnutrition since birth and not only the current conditions; secondly, it can be seen that the range of malnutrition according to Mo(HA) goes from a low of 24.7% in Zimbabwe to a high of 58.3% in Madagascar; thirdly, it is known that infant mortality tends to be much higher in those countries where the proportion of children suffering from malnutrition is large. Thus, in Madagascar and Niger, the percentage of children characterized by serious malnutrition (below three standard deviation) is approximately the same, 20% (compared to only 5% in Zimbabwe) and it is certain that many of the deaths are attributable to this malnutrition. But malnutrition is not the only reason yielding high mortality rates, since in these two countries where the nutritional

conditions appear to be similar, the death rate varies by a factor of one to two. Other variables, such as health services, can explain these differences as will be seen subsequently.

The children who are classified as being malnourished in terms of height for age, or weight for age suffer from the following handicaps. First, from the end of the breast-feeding, until five years of age (the maximum age of the population surveyed), diet limited to cereals like millet and sorghum is unbalanced, because it does not contain enough lipids and protein[6]. Such an unbalanced diet can create a vicious circle: the child is more vulnerable to infection, and when this occurs, the infection lasts much longer. Since poor families cannot afford a balanced diet (which costs significantly more than a millet-based diet, for example) the children suffer from deficiencies which both contribute to slow down growth and to infections. Secondly, practically all children suffer from infantile pathologies (e.g. infected wombs, diarrheas, intestinal parasites, cough, fever) which can lead to weight losses and height stagnation if they are not treated properly and effectively. Poor families often lack the means to pay for care and medicines[7]. These frequent and poorly treated pathologies have a negative effect on the weight and height of a child which is lasting, because it takes several years for the child to reach the weight and height corresponding to his or her age in the reference population (Martorell and Habicht, 1986). Height or weight lags among children can have different causes. Either the quantity of food is insufficient or the diet is inadequate because it is unbalanced (a problem of quality and not quantity) and there is also a lack of care and medicines.

A comparison of anthropometric data of children with that of adults reveals that the percentage of mothers having a weight below two standard deviations from the mean of the reference population is much less in Africa than that of children so classified. This would suggest that the primary cause of malnutrition among children is an unbalanced diet and household incomes too low to provide the necessary health care and required drugs. This observation has led Pelletier (1998) to argue that anthropometric data, in this context, are intrinsically more significant than the measurement of the quantity of food consumed because they reflect the combined effects of the diet and pathologies on an individual's health. Moreover, they reflect conditions obtaining over the long-term; in contrast, information on food consumption is only

[6] Martorell and Habicht (1986) show the decisive contribution of protein to the height of children until age three.

[7] The poorer the families are, the more numerous are the factors responsible for those pathologies, such as an interior earthen floor instead of cement, a lack of potable water and so forth.

available in the short run. Thus, the fact that 20 to 50% of the children under six show signs of serious malnutrition does not mean that all of these children, or at least those between three and five years of age, have suffered from insufficient intake diet (even if this is true for some). Malnutrition is just as likely to reflect the poverty of the parents who cannot buy the necessary elements of a balanced diet at a critical age and cannot adequately cope with all infantile pathologies[8].

In short, it can be argued that anthropometric data for infants turn out to be a better indicator of poverty than those for adolescents or adults[9]. For the latter, a sufficient supply of cereals can prevent serious malnutrition, while it is necessary to spend more on other foodstuffs and services to insure normal growth in an infant. Therefore, signs of serious malnutrition among infants may reasonably be considered a significant indicator of a household's poverty as the following classification suggests[10]:

HA or WA of Children [of mother]	Circumstances of parents
Between -1 (σ) et -2 (σ)	Sufficient potential income but inequitable intra-household allocation and other negative socioeconomic characteristics
Poverty Line	
Between -2 (σ) and -3 (σ) Less than -3 (δ)	Poor Extremely poor

[8] In some instances the state provides some health and nutritional benefits to households. It is important in such cases to add the imputed value of those benefits to the incomes of household receiving those services. This is particularly important in comparing across countries and regions (rural areas are often discriminated against and urban areas favored in a relative sense).

[9] The fact that our poverty indicator (Po) varies between 50 and 80 percent for the countries in our sample (see Table 2) while the range of infant varies between 20 and 50 percent is due to the adoption of two different criteria for poverty and malnutrition, respectively. Clearly the two indicators would be closer if one had adopted as the malnutrition treshold one, rather than two standard deviations below the median of the reference population.

[10] This indicator is only an approximation. Actually, there are a number of reasons why a precise mutual relationship between the health of young children and the division of the population between poor and nonpoor cannot be expressed exactly: there are poor families (or isolated individuals) who do not have young children, and children can suffer from malnutrition even though their father has enough income for their proper nutrition (e.g. because he spends a large part of his wages outside the household or because there is an inequitable distribution of foodstuffs in the household to the father's benefit).

The first category consist of the extremely poor households, i.e. those that cannot insure a minimal consumption of cereals for all its members. Consequently, a lot of adults have a Quetelet index of less than, or equal to 18.5 and because of their physical frailty, they cannot do more than three or four hours of physical labor per day. They are caught in a poverty trap from which they cannot escape because of a their low productivity. Such misery corresponds to serious malnutrition among infants so that many die particularly those below three standard deviations in terms of HAz or WAz. It should be noted that in middle-income African countries, like Zimbabwe, there are few extremely poor families (only 2-3% of the children are below -3 standard deviations). In countries at the bottom of the scale, like Niger, there is a relatively much larger number of such families (17% of the children have a WAz score less than -3 standard deviations).

The second category, i.e. poor households, can satisfy the dietary needs of adults, but lack the means to raise children properly, that is, to pay for the goods and services necessary for normal growth, which leads to serious lags in HAz and WAz (between -2 and -3 standard deviations).

The final category would be those households with sufficient potential income but suffering from inequitable intrahousehold allocation and unfavorable socioeconomic characteristics. In some instances, these households can probably look after their children but are not always able to buy medicines or specific foodstuffs, at the times they are required. In these families other factors such as a low level of maternal education can play a role. An absence of care in the event of disease, or food necessary for a balanced diet, can result from ignorance rather than a lack of resources when mothers are illiterate. In this category children display significant lags in HAz and WAz ranging between -1 and -2 standard deviations.

The above classification of malnutrition and poverty according to the anthropometric data of Table 3 leads to distinguishing between three categories of countries: middle-income countries, poor countries and extremely poor countries. Zimbabwe, Cameroon, Cote d'Ivoire and Senegal are in the first group, with Zimbabwe significantly ahead of the other three. In these countries, extremely poor families (HAz and WAz less than -3 standard deviations) are uncommon, on average 5% or less. On the other hand, between 12 and 20% of the households are poor (HAz and WAz between -2 and -3 standard deviations).

In the extremely poor countries, like Madagascar or Niger, the situation is much more serious, since between 10 and 30% of the children are classified as below -3 standard deviations. These figures reflect real food shortages, especially in rural areas; furthermore, about one-third of the children are classified between -2 and -3 standard deviations.

Half of the population is below the malnutrition poverty line defined by -2 standard deviation, compared to about one-fifths in the middle income countries.
The other 13 countries fall in the category of poor countries.

4. The Interrelationship Between Malnutrition and Poverty

In the analysis that follows we shall use the FGT class of poverty measure (Foster, Greer, and Thorbecke, 1984), which is expressed as

$$p_\alpha = \frac{1}{N}\sum_{i=1}^{q}\left(\frac{z - y_i}{z}\right)^\alpha \qquad (3)$$

where:
α = a poverty aversion parameter
n = total number of individuals in population
q = total number of poor individuals
z = poverty line
y_i = income (or expenditure) of the ith individual below the poverty line where i equals 1,2,...q
As is well known Po is the head count ratio (i.e. the percentage of the population below the poverty line); P1 is the poverty gap; and P2 is the poverty gap square.
In order to compare poverty based on the money metric income criteria with poverty based on the nutritional and health status of infants we derive a malnutrition measure that is the analogue of the FGT poverty measure and can be applied to any continuous distribution of nutrition outcomes (e.g. HAz or WAz).

where
Y_{ref}= malnutrition line (e.g. -2 standard deviations below mean of reference population)
Y_i= nutrition outcome of malnourished child (defined as child with $Y_i < Y_{ref}$)
α = malnutrition aversion parameter
N = total number of children in the sample
q = total number of malnourished children (as defined above)

Note:

If α=0 then $M_o = \frac{q}{N}$ i.e. percentage of children malnourished.

If α=1 then $M_1 = \frac{1}{NY_{ref}} \sum_{i=1}^{q} (Y_{ref} - Y_i)$ i.e. malnutrition gap

If α=2 then $M_2 = \frac{1}{N(Y_{ref})^2} \sum_{i=1}^{q} (Y_{ref} - Y_i)^2$ i.e. malnutrition gap squared

Table 4a. Poverty and Malnutrition Measures
(based on FGT Pα and Mα Classes)

	Country	Po	Mo	P_1	M_1	P_2	M_2
1	Benin	59.95	28.80	0.236	6.112	0.113	2.282
2	Burkina Faso	70.45	37.10	0.324	9.006	0.176	3.583
3	Burundi	76.90	50.00	0.376	2.575	0.213	5.164
4	Cameroon	51.85	28.70	0.224	6.699	0.119	2.731
5	Côte d'Ivoire	53.25	28.10	0.242	6.962	0.128	2.479
6	Ghana	59.50	31.50	0.242	6.962	0.120	2.647
7	Kenya	68.15	35.50	0.387	8.448	0.251	3.369
8	MadagaskarM	77.15	58.30	0.400	15.926	0.231	6.754
9	alawi	82.80	54.30	0.483	15.192	0.316	6.775
10	Mali	70.70	35.70	0.327	10.329	0.178	4.824
11	Namibia	65.70	30.70	0.360	6.380	0.223	2.416
12	Niger	70.55	44.70	0.321	13.036	0.174	6.113
13	Nigeria	70.50	46.40	0.398	14.369	0.259	7.100
14	Rwanda	69.75	52.70	0.299	13.550	0.154	5.469
15	Senegal	57.30	27.30	0.277	6.353	0.164	2.582
16	Tanzania	80.00	46.90	0.506	11.643	0.355	4.777
17	Togo	62.15	33.30	0.243	7.208	0.118	2.646
18	Uganda	62,90	48.10	0.278	12.892	0.147	5.588
19	Zimbabwe	62.65	24.70	0.342	4.519	0.221	1.506

Table 4b. Rankings
(ascending order from poorest to least poor)

	Country	Po	Mo	P1	M1	P2	M2
1	Benin	15	15	17	17	19	18
2	Burkina Faso	8	9	10	9	10	10
3	Burundi	4	4	6	19	8	7
4	Cameroon	19	16	19	13	17	12
5	Côte d'Ivoire	18	17	18	16	15	16
6	Ghana	16	13	16	12	16	13
7	Kenya	10	11	5	10	4	11
8	MadagaskarM	3	1	3	1	5	3
9	alawi	1	2	2	2	2	2
10	Mali	5	10	9	8	9	8
11	Namibia	11	14	7	14	6	17
12	Niger	6	8	11	5	11	4
13	Nigeria	7	7	4	3	3	1
14	Rwanda	9	3	12	4	13	6
15	Senegal	17	18	14	15	12	15
16	Tanzania	2	6	1	7	1	9
17	Togo	14	12	15	11	18	14
18	Uganda	12	5	13	6	14	5
19	Zimbabwe	13	19	8	18	7	19

Table 4a gives the poverty and malnutrition estimates, for the 19 countries in our sample, for P_o, P_1, P_2, M_o, M_1, and M_2, respectively. In turn, Table 4b provides the country rankings in ascending order from the poorest to the least poor for these six measures. Based on the data in Table 4 the correlation coefficients between pairs of M_α and P_α were computed in Table 5. It can be seen that the correlation coefficient between M_o and P_o is relatively high, i.e. 0.80 (the corresponding Spearman Rank correlation coefficient is 0.82). The correlation coefficients between M_1 and P_1, and M_2 and P_2 were all around 0.45-0.47, respectively Figure 1 reveals graphically the plot of Mo and Po. While an upward sloping regression can be read into this plot, it is also interesting to note that there are significant differences in the level of malnutrition (Mo) for the five countries that display poverty head count ratios (Po) around 70% (i.e. Burkina Faso, Mali, Niger, Nigeria, and Rwanda). The range of malnutrition in these five countries (with approximately equivalent poverty headcount ratios) is from 35.7% in Mali to 52.7% in Rwanda. Clearly, other factors besides income affect malnutrition and health as will be made clear subsequently.

Table 5. Correlation between Mα and Pα

Between	Mo and Po	M1 and P1	M2 and P2
Correlation Coefficient	0.80	0.46	0.47
Spearman Rank Correlation Coefficient	0.82	0.47	0.45

The relatively high coefficient of correlation between Po and Mo appears to be directly related to the use of a flexible absolute poverty line. This concordance may seem normal, but it does not occur when Mo is correlated with other poverty indicators and macroeconomic data, appearing in Table 6. This issue is discussed in some detail subsequently in a subsequent section.

Table 6. Malnutrition and Poverty Indicators (R^2)

	Mo(HA)	$Mo^* = \frac{Mo(HA) + Mo(WA)}{2}$
Po Ali-Thorbecke	0.64	0.63
Po (FAO)	0.16	0.04
c(FAO)	0.29	0.10
HPI*	0.02	0.07
Po (WB$1)	0.37	0.19
Po(WB$2)	0.41	0.45
% population with access to potable water	0.42	0.36

In Table 7, we also compute the correlation between Mo (HA) and Po and the log of Mo (HA) and the log of Po obtaining an R square of 0.64 in both cases (the coefficients of this linear function are also significant). The utility of this functional form is obvious: the coefficient of Po indicates the elasticity of malnutrition with respect to poverty (Po). At a threshold of –2 standard deviation it reaches 1.64; thus a 10% increase in the proportion of the poor increases by 16.4% the proportion of children suffering from serious malnutrition.

Table 7. Malnutrition (height for age) and Poverty Indicators

variable	constant	Po Ali-Thorbecke	R^2
Mo(HA)	-26 (2.2)	0.97 (5.5)	0.64
log Mo(HA)	-3.3 (2.6)	1.64 (5.5) (a)	0.64

note: Po in log form
this table and those which follow give the absolute value of the t statistics in parentheses.

We saw in an earlier section how a lack of care and medicine impedes normal growth. Infantile pathologies can last months if a child is not looked after and during this period and his or her height and weight can stagnate. Thus, it can be assumed that countries that spend more on health care are more successful in avoiding severe malnutrition among infants. This assumption is tested by introducing a variable h, which corresponds to the share of expenditures in GDP, or, alternatively, a dummy variable which take the value of one for the countries where h is higher than the average in the countries included in the same grouping of GDP per capita or zero, otherwise[11]. Thus in Table 8 Mo* and logMo*, respectively are regressed on Po, h, a health dummy variable and the percentage of households having access to potable water. The R^2 's range between 0.63 and .87. Including a health variable and potable water increases the explanatory power of malnutrition.

Table 8. Explanatory variables influencing malnutrition

Dependent variable	constant term	Po	Share of health ex–penditures in GDP	Health dummy variable	Potable water	R^2
Mo*	-16 (1.7)	0.78 (5.4)				0.63
	-13 (1.6)	0.83 (6.7)	-3.8 (2.7)			0.75
	-22 (2.8)	0.91 (7.7)		-7 (3.5)		0.79
	-12 (6.5)	0.86 (6.6)		-8 (3.5)	0.12 (1.3	0.87
log Mo*	-2.8 (2.4)	1.51 (5.4)[a]				0.63

log of Po

[11] If statistics were available for all the countries in our sample it would be more accurate to use primary health expenditures (e.g. for health centers, first aid centers, rural clinics and dispensiaries, etc.) rather than total health expenditures since expenditures for modern hospitals –particularly in urban areas-have no effects on the treatment of simple infantile pathologies in rural areas.

Having shown that malnutrition depends on the percentage Po which, in turn, depends on μ, a direct relationship between malnutrition and per capita income can be simulated. Knowing that Po is a function of g, and the distribution of income, if one abstracts from differences in distributions, one obtains: indicator of malnutrition (e.g. Mo(HA)) = f(Po); and since Po = μ(g) (which has a quadratic form); it follows that an indicator of malnutrition (e.g. Mo(HA)) = h(g).
A function h(g) is sought which fits the anthropometric data best. This relationship is not linear, yielding a convex curve towards the origin when the x-axis represents an indicator of malnutrition and y is the abscissa. Using the following equation:

$$\text{Log Mo (HA) (or logMo*)} = a_o + a_1\mu. + a_2\mu^2 , \qquad (5)$$

gives such a relationship, where

$$M_o = \frac{M(HA) + M(WA)}{2}$$

The estimated results obtained from the above regression are satisfactory since the coefficients of g are highly significant and the values of R2 range between 0.6 and 0.8 (cf. Table 9 top panel). If it is assumed that these two variables reflect approximately the percentages of the poor, these two regressions (which have coefficients very close to each other) indicate a satisfactory relationship between average income and poverty.\
Having shown that health expenditures have a significant effect on malnutrition, we then verified the role of this variable by adding this dummy variable as an explanatory variable of log of Mo (HA) and Mo* in the regression equation (see table 9, lowest panel). The importance of health expenditures is confirmed: the coefficients of the dummy variable are significant and relatively large. For example, when μ is equal to $400, the value of Mo (HA) drops from 33 to 30% if the level of health expenditures is higher than the average.

Table 9. Malnutrition measures Mo(HA) and Mo* regressed on mean income (μ)

Dependant variable[a]	Constant term	$a_1\mu$	$a_2\mu^2$	Dummy[b] health variable	R^2
log Mo^*	4.2.(41)	-0.0022 (6)	0.0000012 (4.7)		0.75
log Mo(HA)	4.2.(31)	-0.0021 (4.3)	0.0000011 (3.4)		0.62
log Mo^*	4.3 (41)	-0.0024 (6.9)	0.0000013 (5.7)	-0.12 (2.1)	0.81
log Mo(HA)	4.3 (28)	-0.0023 (4.4)	0.0000012 (3.6)	-0.095 (1.1)	0.65

a) $Mo^* = \frac{Mo(HA) + Mo(WA)}{2}$

b) the health dummy variable takes the value of 1 for the countries where the proportion of health expenditures to GDP (h) is higher than the average in the countries included in the same grouping of GDP per capita and zero otherwise.

5. Comparisions of Alternative Methods of Estimating Malnutrition

We found that our estimates of poverty based on an adjustable absolute poverty line were relatively closely correlated with observed infant malnutrition indicators derived from DHS. The next question we address is to compare the extent to which other estimates of poverty, such as those of the World Bank (1998) and UNDP (1998), and more direct estimates of malnutrition among the overall population (FAO, 1996) are correlated with the observed infant malnutrition indicators presented in this paper (see Table 6). The World Bank has established, somewhat arbitrarily, two poverty lines of $1 and $2 a day per capita, respectively. These two poverty lines have been used to calculate the percentage of poor in each country[12]. We denote these two poverty lines as Po (WB $1) and Po (WB $2), respectively. The correlation between the lower World Bank poverty line and the malnutrition indicators was rather weak with R^2's of (0.37 and 0.19, respectively). The correlation was slightly higher for the higher of the two World Bank poverty lines (0.41 and 0.45).

Next we use a modified Human Poverty Index (from the UNDP). This index combines different indicators including life expectancy (with a

[12] For example, in the World Bank, World Development Indicators 1998, the tables on poverty present the percentage of poor by country according to the two poverty lines above in addition to the poverty lines defined by the respective national statistical services. Thus these thresholds have an official status and are a reference source for poverty analysis.

weight of one-third) and an indicator of malnutrition among children (assigned a weight of one-ninth). We excluded these two variables and retained the others, i.e. the proportion of individuals who are illiterate, who have access to potable water and have access to health services, respectively. This yielded a modified poverty index denoted as HPI*. As the 1998 UNDP Report only gives these figures for 14 of the 19 countries in our sample, the regressions that were run between Mo (HA) and HDI* and between Mo* and HDI* were limited to 14 countries. It can be seen from Table 6 that the corresponding R^2 are extremely low.

The percentage of the total population affected by malnutrition, Po (FAO), is estimated by the FAO on the basis of three variables: (1), the quantity of calories per capita available in each country, c(FAO); (2), the distribution of calories among households; and (3), a country specific caloric threshold specified by the FAO below which malnutrition occurs. We estimated the R^2 between our Mo (HA) on the other hand, and Po (FAO) and c (FAO), on the other hand, respectively. The same regressions were run for Mo*. As can be seen from Table 6 the R^2 obtained were very low ranging from 0.04 to 0.24. It appears clear that the FAO estimates of malnutrition for the whole population hardly appear to have any relationship with estimates of malnutrition observed among infants under six years of age.

Finally, the correlation between the proportion of the population with access to potable water and our two malnutrition indicators was of the same magnitude as that between Po (WB $2) and our two malnutrition indicators.

What the above results demonstrate is that of all the variables we have used as predictors of observed malnutrition among infants based on the DHS surveys (namely, our Mo (HA) and Mo* indicators), the one that performed by far best is the poverty head count ratio derived according to the AliThorbecke adjustable absolute poverty line, method, i.e. Po (AT). It is noteworthy that the two World Bank poverty measures, the two FAO malnutrition measures, the modified Human Development Indicator and the share of the population having access to potable water performed significantly worse in predicting infant malnutrition than Po (AT).

6. Conclusions

The criterion of poverty selected in this paper is the state of malnutrition and health of infants. We define as poor those households whose children 5 to 59 months of age display signs of severe

malnutrition based on anthropometric measurements and, in particular, on the height-forage-z-score. Although poverty is a highly multidimensional concept, inadequate nutrition and poor health appear to be among the most critical determinants of the capability of an individual to function in society.

Most estimates of poverty are based on poverty lines derived from the Food-Energy-Intake (FEI) or Cost-of-Basic-Needs (CBN) approaches- both of which are anchored to nutritional requirements. Basing estimates of poverty on malnutrition indicators as opposed to estimates derived from money metric food consumption measures obtained from the FEI or CBN methods has a number of advantages. First, malnutrition measures derived from anthropometric indicators reflect an outcome (or health output) variable. Instead conventional poverty estimates reflect a nutritional (or health) input variable, i.e. the required calories bye a given household. Even if a child is provided with an adequate amount of calories his/her health can be affected by being fed an unbalanced diet (based largely on cereals)- a problem related to the quality rather that quantity of the diet- and being vulnerable to a variety of infantile diseases and pathologies. A household is poor if the parents cannot provide or have access to the necessary health care and balanced diet, even through satisfying their caloric requirements.

Secondly, malnutrition indicators reflect the nutritional and health status of an individual. In contrast, poverty estimates derived from consumption data from income and expenditure and living standard measurement surveys are available only at the household level. Given how little is known about intra-household allocation the actual consumption of individual household members derived from using equivalence scales and household economies of scale are gross approximations at best.

An interesting result of this paper is the relatively high correlation obtained between the malnutrition indicators drawn from the Demographic and Health Surveys of 19 SubSaharan countries, and poverty estimates derived from the use of an adjustable absolute poverty line (increasing as a function of mean income) proposed by Ali and Thorbecke (2000). Other poverty and malnutriton indicators used by the World Bank, UNDP and the FAO performed significantly worse in predicting infant malnutrition than the Ali-Thorbecke poverty estimates used in this paper.

A final implication of the analysis in this paper is that malnutrition indicators (such as the height-for-age-z-scores) could be considered as a good alternative for the more conventional poverty measures derived from nutritionally- anchored survey information.

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Agricultural Development and Poverty Reduction in the Sahel

John H. Sanders

1. Introduction

The periodic crises in agricultural production and the wars in Sub-Saharan Africa are the main public perceptions of the sub-continent. So the projections for the future from the media tend to be of the Gloom and Doom variety. Actually the agricultural systems of Sub-Saharan Africa have made some impressive achievements and there is potential to make more even in the more difficult regions where the poor are concentrated.

The focus of the World Bank has been returning to the principal developmental concern of the ‘70s after a twenty year detour into Structural Adjustment. Two decades of convincing the developing world that if they just got the government out of its intrusive role in the economy and let prices function, that everyone would live happily ever after, was probably enough of that.

Now many are back again to the questions of how to influence technology introduction, migration, economic policies, and agricultural development to more systematically attack poverty and malnutrition. In this paper the focus is on the introduction of new technologies in semiarid regions of West Africa. Due to the concentration of rural poverty in these regions more rapid technological change would also have a substantial effect on rural poverty.

Some argue that maximizing economic growth is often the best strategy for reducing poverty (Gardner, 2000). Fortunately, there are also efficiency reasons for accelerating the introduction of technological change in semiarid regions. When neither water availability nor soil fertility are constraining, semiarid regions have less disease and more sunlight than higher rainfall regions. So societies need to take advantage of this as well as attaining the social benefits of alleviating poverty by raising the incomes of the inhabitants of these regions.

To evaluate the role of agriculture in reducing poverty in the semiarid regions, let’s consider three basic questions:

1. How have the agricultural research and extension systems been functioning in the regions with adequate rainfall?
2. Are there differences in these systems between increasing productivity and helping poor people, (the efficiency-equity problem)?
3. What are the appropriate agricultural development strategies for moving into the lower rainfall regions where there are high concentrations of poor people?

The focus will be on the Sahelian countries and Ethiopia but the analysis is relevant for the twenty Sub-Saharan countries with substantial dependence upon their semiarid regions.

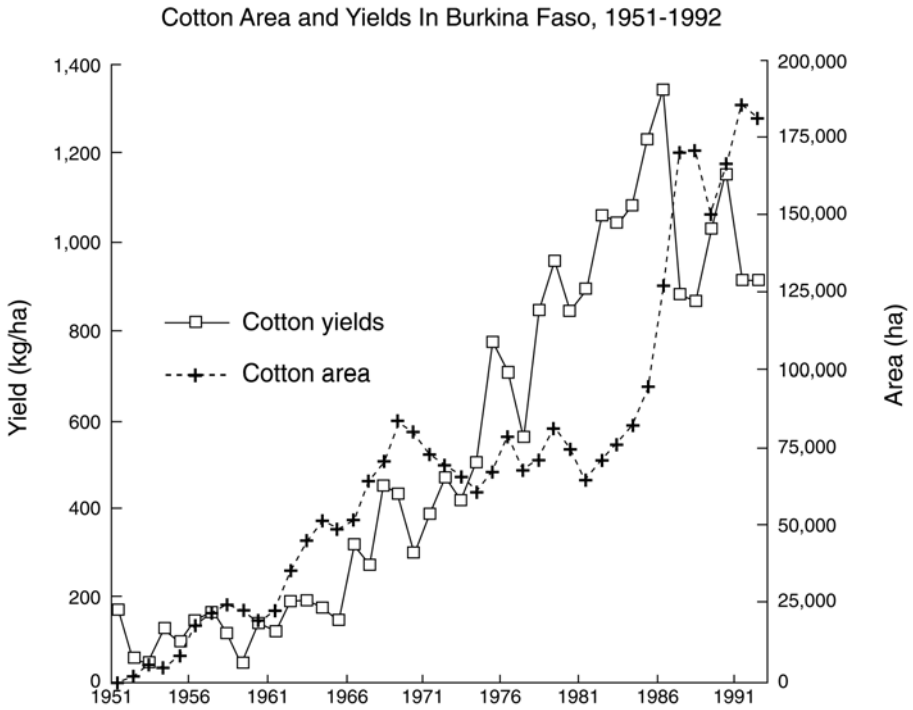
2. Performance of Agriculture

There have been impressive successes with both cotton and maize. Notice the increase of cotton yields in Burkina Faso from the mid '60s to the mid '80s (Figure 1). This is impressive growth and it happened all over Franco-phone Africa. There were a stream of new cultivars, increasing inorganic fertilizer use, and higher farmer incomes. There was also a para-statal cotton agency, facilitating input use, providing credit, guaranteeing prices and marketing the cotton. In recent years yield growth leveled off here as in the US. However, breeding switched then to higher fiber quality objectives in both places. To reflect this it would be necessary to redo the axis to reflect the higher economic value of the improved fiber.[1]

Similarly, there were substantial gains in maize productivity during the '80s (Figure 2). From 1980-1992 yield growth rates for Ghana, Mali, and Burkina Faso were 4.8, 6.7, and 5.7% (Sanders et al, 1996, p. 59). These are also impressive yield gains. The gains were not as dramatic as in cotton and in many countries the higher input use decreased again after the para-statal removed the guaranteed price supports. Nevertheless, as with cotton there were new cultivars available which could be combined with soil amendments (manure and some inorganic fertilizers) to give higher yields. The new technologies were adopted quickly and gave high rates of return to research. There were substantial increases in maize productivity and production.

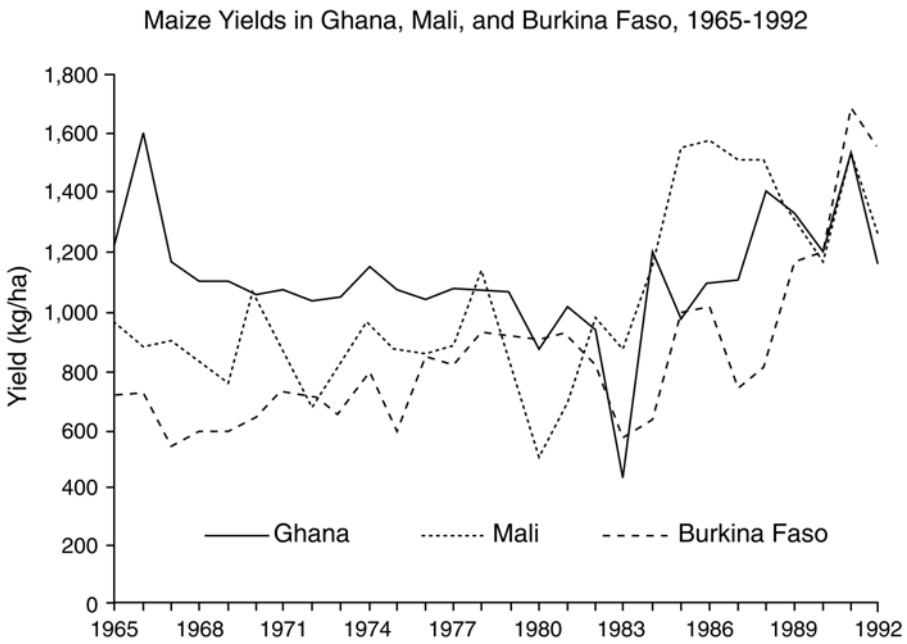
[1] The other relevant question is who benefits from the higher valued fiber and even from the increased cotton yields. Some of the benefits undoubtedly go to the farmer because the cotton regions are the most prosperous zones in the Sahelian countries. However, there are monopsonistic buyers for the cotton so substantial potential to avoid paying the competitive prices. World Bank estimates are that farmers receive a much lower proportion of world export prices for lint in the Sahel than in other regions of Africa with more competition in cotton marketing (Gary Purcell, personal communication 1999).

Figure 1. Cotton area and yields in Burkina Faso, 1951-1992.



Source: Sanders et al., 1996 p. 55.

Figure 2. Maize yields in Ghana, Mali, and Burkina Faso, 1995-1992



Source: Sanders et al., 1996, p. 59.

The cotton parastatals then did not know what to do with the maize surpluses as they had guaranteed prices. So they dropped the programs. But they demonstrated again that with inputs and price supports they could rapidly increase productivity and production. So the technical problems of increasing output in the Sahel are not that difficult at least in the higher rainfall regions.

3. Extending the Gains to Poor People and Lower Rainfall Regions

As Sen (1981) has pointed out in his analysis of famine, a collapse of agricultural output is not always the principal cause of famine. Rather peoples' ability to acquire food can be critical. There are cases of successful agricultural production where in nearby regions people go hungry because they do not have the entitlement (income, plus assets they could cash in, plus any insurance, or state income support) to obtain the food.

For example, in the second half of the '90s Ethiopia attained impressive success in increasing productivity of the cereals with widespread diffusion of new cultivars, credit, inorganic fertilizers, and extension. Nevertheless, at the end of the '90s the FAO/ World Food Program was making urgent appeals to donors for emergency food aid for 8 to 9 million of their 62 million people after good crop years in the prime zones (Georgis et al, 2001). Some inter- regional food trade takes place but it was insufficient especially when incomes collapsed in specific regions with inadequate or excessive water. Even with the price declines of food in the higher rainfall regions the poor in the adversely affected regions could not pay for it. Eliminating poverty and malnutrition involves more than new technology introduction into agriculture.

Another alternative for low income regions or countries has been to look outside agriculture. Sachs of Harvard has suggested that many of the countries of Africa should concentrate on labor intensive manufacturing. But if Sahelian countries increased their production of T shirts, could they sell them in developed countries? Could they compete with the lower labor costs of India or China? Perhaps in another two decades there will be more regions in the world similar to Hong Kong, that essentially are dependent upon agricultural imports. With the high populations presently in agriculture in African countries, their low incomes, and their dependence upon local food supplies, a

principal policy concern of these governments is to keep food prices down and avoid being overly dependent upon food imports.[2]

In West Africa food prices are kept depressed by government policy to increase imports when supply declines with poor weather. With good weather or with technological change prices collapse due to the price inelasticity of demand.[3] So not only do these depressed prices from successful production reduce farm level profitability, but public policy reduces the profits in the adverse years. Both then discourage input purchases and capital investment for the intensification process.

In Sub-Saharan African agriculture, especially outside the adequate rainfall zones, soil fertility has been depleted by continuing population pressure on the limited cultivable area. This population pressure has been eliminating the traditional means of restoring fertility, fallow rotation. Hence, farmers need to replace the essential nutrients with input purchases. Higher output prices in the short run[4] and less output price variability are required for farmers to purchase more inputs and invest more in their farms.

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[2] There is presently a world cereal war in which developed countries pay their farmers income subsidies, often based upon production, encouraging world cereal price collapse. The objectives are to capture larger world market shares and to obtain political support from farmers. There are high costs to taxpayers in the US and the European Union for these programs. In fiscal year 2000 there were 28 billion dollars paid to US farmers in subsidies and disaster aid (Chicago Tribune, Oct. 12, 2000). EU subsidies have been estimated to cost their taxpayers twice those in the US (Binswanger and Townsend, 2000, pp. 1078, 1079) Developing countries should take advantage of these lower world cereal prices when they can. The questions to their policy makers are how long this will continue and then how they will pay for the higher priced cereals if they allow their agriculture to stagnate now.

[3]For poor people there are often few substitutes for their basic commodities so with higher prices they still try to maintain their consumption. As prices decrease with good weather or rapid introduction of technology there is only so much sorghum/millet or cassava that people can eat so prices collapse. Once people have more or less their basic needs, they don't have any interest in buying more. For the basic food crops the strategy needs to be to combine technology introduction with the identification of new markets.

[4]In the longer run the continuing introduction of new technology will lower production costs and allow prices to decline. In the short run (next five years) governments need to make commitments to their farmers so that farmers have confidence in purchasing inputs and making investments. Developed countries have been excellent in recent years in supporting their agriculture and maximizing technological change there. They still do not know how to phase out the subsidies. So far there have not been taxpayer revolts in either the US of the European Community about the size of these subsidies predominantly captured by the larger farmers

So if agricultural prices need to be higher so that farmers can invest in inputs to increase soil fertility, what about the other objective of helping poor people to eat more? So far donors and governments have concentrated on food aid and food imports to keep food prices down. But there are two principal determinants of the demand function of poor people for food: food prices and their incomes. To get agriculture moving with input purchases and investments by farmers, the concentration needs to be on increasing the incomes of poor people rather than on manipulating food prices. For example, when weather is bad in some regions it is usually not bad in all regions. If donors purchase food from one region to distribute in other regions, that would be more beneficial for stimulating country growth than food aid and food imports. Some of the donors did this in response to the adverse weather conditions in Burkina Faso in 1998. However, the apparent policy of the US now is to expand the role of the NGOs by monetising food aid or letting NGOs sell increasing quantities of food and then utilize these funds in their development programs. Food aid may be more acceptable to US taxpayers than monetary flows but it will continue to disrupt domestic incentives in developing countries to improve agriculture.

Moreover, even in those countries where prices have been kept artificially low by government intervention in poor agricultural years and by natural economic factors in good agricultural years many people in the society have not been able to eat adequately to eliminate chronic and acute malnutrition.

So what needs to be done? Let’s look in more detail at one specific country Burkina Faso.

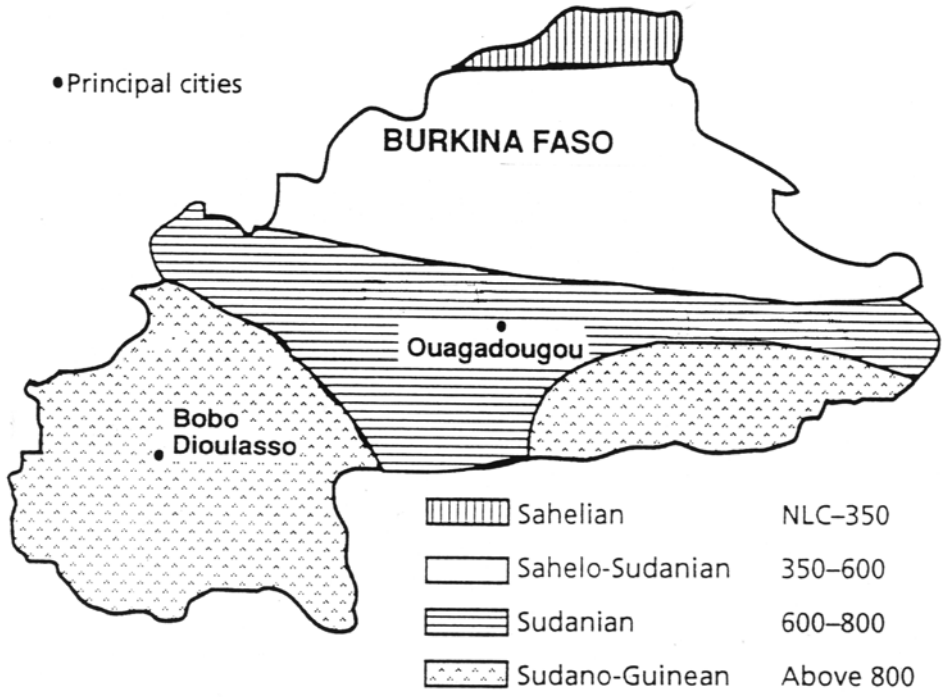
4. Agricultural vs. Poverty Regions and the Constraints to Development

In one of the agricultural strategies that all of the Sahelian countries are now developing, Burkina Faso divides the country into two zones, an agricultural region and a poverty zone (Fig. 3).

The agricultural region is the Southwest and most of the South. The cotton sector is concentrated in the Southwest. Here rainfall is adequate to insure a good response to inorganic fertilizers in most years. Soils are better than in much of the country. Infrastructure investment has been made and there are input and output marketing systems, including research centered around cotton but extending to the other crops in the cotton production systems. In this region the principal

policy/investment recommendations of the strategy document are to improve the efficiency of the input and product markets.

Figure 3. Climatic zones in Burkina Faso.



Source: Sanders et al. 1996, p. 73

Most of the rest of the country is considered to be a poverty zone. Here low and irregular rainfall, poor soils, and low asset positions of farmers require a very different approach. Input markets are written off as farmers do not have the funds to purchase inputs.

Complex soil fertility strategies to substitute for inorganic fertilizers are recommended. Little mention is made of water harvesting in spite of the importance of this technique or irrigation in other dryland regions that have successfully developed. There is also little mention of product markets.

What is supposed to happen in these poverty zones? Very small or marginal gains in income are possible with the various measures recommended, such as improved seed, greater use and/or improved quality of manure, rock phosphate, inter-cropping of cereals and legumes. Once these marginal income gains are attained, farmers sit and wait for industrial development in the capital or in the coastal countries. Lately that industrial growth has either been slow or

associated with minimal employment growth; hence, a decade or two of waiting is implied before out-migration enables a welfare increase of this sitting rural population and more extensive land use in the region.

Should the Sahelian countries buy into this waiting game for most of their population? Is most of the Sahelian crop area too marginal for agriculture for us to worry about the functioning of the input and output markets there? If we compare the Sahel with other dryland regions in the world, the answer to both of the above is clearly no.

Dryland areas have the potential of a comparative advantage over higher-rainfall regions if increased water availability can be combined with higher soil fertility. With these two additional components, dryland regions have less plant disease problems and more sunlight. Both of these advantages are substantial ones. The trick is to combine the water harvesting with the soil-fertility improvement. With these two inputs, there is a substantial change. It then will be profitable to introduce new cultivars and often organic fertilization to complement the inorganic fertilization by holding the nutrients and water in the soil.

5. Niche Crops and the Traditional Cereals

With the emphasis on markets and demand-induced technology development, many have put the niche crops at the center of crop development activities for these lower rainfall regions. To what extent will the agricultural development of countries, such as Burkina Faso, be influenced by higher export earnings from string beans, fruits and vegetables under irrigation? In East Africa, flower exports to Europe have grown very rapidly. These niche crops are activities that a small number of farmers will produce for export with high technology. A requirement will be good marketing information and infrastructure. These are very specific markets with high quality requirements that can be saturated. These are also technologies with sufficient earnings to pay for extension and research services. So specialists can be engaged in both the extension and research sectors to service them.

Meanwhile, there are advantages to looking again at the traditional dryland crops in the region in the same analytical fashion, markets first. The traditional crops of the low-rainfall regions of the Sahel are sorghum, millet, and cowpea. With their evolved tolerance to drought and low soil fertility, they have become the staple food crops of most of the Sahel and even the northern areas of the coastal countries. Have they now become relics useful only to maintain genetic diversity and a food reserve in bad years but not very interesting for a research focus on increasing productivity?

What happens in the developed countries? In Texas, Nebraska, and Kansas as rainfall becomes too marginal and irregular for maize, farmers plant sorghum. With a small price discount for quality (10%), sorghum becomes an important component of feeds in the United States. And in the developing countries? As the development process of income growth occurs, the first major shift is the rapidly increasing demand for a higher quality diet, including animal protein, fruits, and vegetables. Brazil and Honduras illustrate this process of demand growth for products, such as poultry, occurring at almost 10% rates for one to two decades. No developing country has been able to respond to these types of demand shifts for grains without substantially increasing its imports. This process of rapid introduction of poultry products is ongoing now in Botswana with its last decade of rapid economic growth and is beginning in Senegal, Zambia, and Kenya.

What needs to be done to convert the traditional food grains to feed grains? In Senegal, maize is being imported as the principal component of the ration. Maize production can be increased slightly in Senegal but the primary cereal is millet. Millet is a good feed. Millet production and productivity can be substantially increased, as will be discussed later. To sell millet to feed producers, minimum qualities and quantities needs to be assured to the feed mixer. This is something that organized farmers' groups could do.

What about the people who depend upon millet as a food grain? One of the principal constraints to the introduction of new technology with the traditional food crops is the low profitability and the price collapse from the inelastic demand for principal food staples when weather is good or new technology is rapidly introduced. The advantage of a demand shift is to encourage rapid technology introduction while maintaining in the short run higher prices, higher profitability, and a moderating or smoothing of the price-collapse effect from output increase. The increased demand encourages the rapid introduction of technological change. These two activities of demand expansion and technology introduction need to be undertaken simultaneously. In the longer run as new technology reduces farmers' production costs output prices can fall without affecting as much farmers' profits and then both farmers and consumers can benefit.

So we need a new view of the traditional cereals, sorghum and millet, based upon this prospective demand increase for feed grains. There will still be a lag before income growth is sufficient to induce these rapid demand shifts to a higher-quality diet in most Sahelian countries, perhaps another five to ten years. The developing countries that have gone through this process have failed to respond to these demand shifts by producing the feed grains domestically. Hence, the Sahelian

countries need to be concerned with these demand shifts now and to anticipate them. For smaller demand shifts it is useful to identify the factors enabling the growth in urban rice consumption in the last two decades in the Sahel. One important factor is the greater availability of processing-preparation technologies for rice than for the traditional cereals. this appeals to urban women since the opportunity costs of their time increases in urban areas. These same technology processes are being adapted to sorghum and millet as the recent processing and sales of coucous of millet in Senegal and cookies from the new white sorghums in Mali have demonstrated.

So on the demand side the potential for the traditional cereals and other food crops has been substantially underestimated.[5] What about the supply side? Are there technologies available to rapidly shift the supply curve outward in these lower rainfall regions?

6. Water Harvesting and Inorganic Fertilizers

The principal constraint to increasing crop yields in semiarid regions is clear from the definition of the region, lack of water.[6] In much of the semiarid zone irrigation will not be both technically and economically viable. In those soils with crusting or other runoff problems water harvesting will need to precede soil fertility improvements. On the sandy soils where rapid infiltration rather than runoff is the water availability problem the water harvesting technique can be with organic fertilization or even higher plant densities (Shapiro and Sanders, 2001; Shapiro et.al, 1993).

The important point here is the combination of increased water availability with moderate levels of inorganic fertilizers. This combination has been repeatedly shown to approximately double crop

[5]As already mentioned the grain legumes are an especially interesting case from the perspective of future markets. So we will consider cowpeas, pigeon peas, and other grain legumes below.

[6]On sandy soils the argument has been made that the problem is soil fertility rather than water availability. In these areas the principal water problem is infiltration. Increasing soil fertility is associated with increased plant bio-mass on the surface and in the ground. This has been shown to result in increased water use efficiency. Clearly, water availability and soil fertility have to be simultaneously undertaken. Then methods for doing this will depend upon the soil types with fundamental differences between soils where runoff is the principal problem and those where infiltration is too rapid, the soils with more clay and sandier soils respectively.

yields while decreasing the riskiness of fertilization alone (Table 1; Sanders et al, 1996, p.78).

The other important point to make here is to distinguish between the types of fertilizer and their objectives. Inorganic fertilizers are designed to provide low-cost sources of the principal nutrients, nitrogen, phosphorous and potassium. Nitrogen and phosphorous are the principal soil nutrient deficits in most semiarid regions and potassium will quickly become limiting as cereal yields are increased with the other two nutrients. Organic fertilizers are useful for increasing water and nutrient retention capacity, especially in the sandy soils. Without their inclusion with the inorganic fertilizers on sandy soils, the principal nutrients can be rapidly leached below where the plant roots can tap them. Organic fertilizers also increase biological activity and can provide micro nutrients. Unfortunately, they are usually not cost efficient providers of the major nutrients (Sanders et al, 1996, p.64) and are usually not available in sufficient quantities for this function.

The bottom line on soil fertility and agricultural chemicals in general is the need to avoid looking for a magic solution. If everywhere that crop yields have been substantially increased inorganic fertilizers have been involved, is it really likely that Sub-Saharan Africa will find new solutions to the soil-fertility problem without them?

Table1. Yields and Percentages of Farmers Taking Cash Losses from Fertilization and Tied Ridges in Sorghum Production in Farm Trial Villages, 1983 and 1984

Year/Village	No. of Farmers	Traction Source	Yields				% of Farmers Losing Cash	
			Control	Tied Ridges	Fertili-zation	Tied Ridges and Fertilization	Fertili-zation	Tied Ridges and Fertilization
1984								
Nedogo	11	Manual	157	416	431	652	27	9
Nedogo	18	Donkey	173	425	355	773	50	0
Bangasse	12	Manual	293	456	616	944	8	17
Dissankuy	25	Ox	447	588	681	855	28	0
Diapangou	19	Manual	335	571	729	1006	26	0
Diapangou	19	Donkey	498	688	849	1133	21	0
Diapangou	19	Ox	466	704	839	1177	5	0
1983								
Nedogo	3	Manual	430	484	547	851	56	0
Nedogo	11	Donkey	444	644	604	962	58	42
Bangasse	12	Manual	406	493	705	690	21	17
Diapangou	24	Manual	363	441	719	753	8	8
Diapangou	25	Donkey	481	552	837	871	12	16
Diapangou	25	Ox	526	578	857	991	20	12

Source: Sanders et al., 1996

The observation that farmers in semiarid regions do not purchase inputs, therefore they will not purchase inputs in the future needs to be examined. Is the failure to purchase inputs a problem of farmer liquidity (access to capital) or of their being convinced that a given technology is sufficiently profitable to make the investment? We have observed the flows of remittances to farmers in semiarid regions, their savings invested in the highly liquid livestock, and their ability to come up with capital for weddings, funerals, and livestock purchase. Their problem of low input purchases is not the supply of capital but the demand for the new technologies. So we need to demonstrate to farmers the potential of these new technologies and to find new sources of demand expansion for their traditional crops.

One consequence of the structural adjustment programs was a decline of most food crop seed production. Public seed companies were either being eliminated or ordered to become more profitabile. The private seed sector has not been filling the gap. Rather private seed companies were concentrating on hybrids and on crop activities in the prime agricultural areas. Food crops outside the prime agricultural areas were ignored.

Community seed production schemes with NGO and/or national research-scientist support have been used to fill this gap. These schemes can function as long as there is a high level of well-trained, technical input. As soon as the pressure of other activities occurs for the scientific staff of the national research centers or extension agencies, there tends to be a decline in the quality of seed production.[7]

The problems of quality control among small farmer seed producers are serious, especially the needs for roguing and isolation. Farmers need substantial training to handle these technical problems of seed production.

In the long run for the semiarid sector, some specific policies to encourage the evolution of private sector seed production are necessary. Breeders' rights, in which the individual developers of new material directly benefit from its diffusion to farmers, may be a start in encouraging small private seed concerns specialized in specific activities. Breeders are often innovators and entrepreneurs. They may not have the capital themselves for starting a seed business but they probably know people, who do.

The evolution of private sector seed producers could also allow the public-sector company to return to their previous function of providing quality seed to small farmers, open- pollinated varieties, and other seed

[7] The NGOs could themselves hire highly trained agricultural scientists and a few of the larger ones have done this.

functions presently not profitable enough or too risky for the private sector to undertake.In this scenario the public sector becomes the orphan crop seed producer until the sector becomes profitable enough for the private sector to enter. Here it becomes critical for the public sector to create a bridge to the evolution of expanded activities by the private sector by not subsidizing the costs of seed production. Moreover, the public sector needs to encourage the private sector to take over its activities once the public sector has demonstrated a potential profitable demand for these activities.

Fertilizer distribution is another critical activity for the entire country. But as with the seed sector, improving the functioning of this market in semiarid regions will be very difficult until there is increased water harvesting or irrigation in these regions. Once more water is available, demand increases substantially for inorganic fertilizers. But water availability is the prerequisite.

7. **Product Markets**

The concept of demand driven growth for determining priorities in agricultural research institutions is now widely disseminated. This should not be interpreted as a license to neglect semiarid regions as has been in the case of Ethiopian seed production (Georgis et al, 2001). Rather there is substantial potential for increasing yields of the food crops in semiarid regions. We already discussed the potential role of the traditional cereals as feed grains.

Presently there is substantial research effort in the Sahel to identify and expand the marketing of traditional cereals by improved processing, marketing new food products, or looking for new markets in bread or beer. In the two West African networks for millet and sorghum, a major proportion of their activities (as reflected in the subject matter of their workshops) is put into this search for new markets and increased quality control.

Grain legumes provide one of the most interesting illustrations of the need to take a new look at dryland regions. The importance of cowpeas as a cash crop both for hay and for grain has been increasing substantially across the Sahel. As with the cereals, higher input levels are needed to increase productivity, especially phosphorus, but also the control of field and storage insects. The combined gains in sales and productivity will enable improved nutrition. With its high protein levels, food use of grain legumes is clearly important to many small farmers.

The most interesting recent case has been the search for new export markets for pigeon peas in Kenya. ICRISAT had identified the characteristics of pigeon pea required for making "dhal." Then an ICRISAT extension specialist went the next step of putting producers and exporters in touch. The components of the integrated system then were "access to well organized markets, distribution, and post harvest systems; effective market information; and technologies that allow them (farmers) to be price and quality competitive." (Jones, Freeman,Walls and Londner 1999, p. 3).

The combination of quality control[8] in all stages of the market and searching out new markets were very innovative for an international center and more characteristic of a private company. The importance of quality control in producing specific cultivars and then maintaining that quality control in the marketing channels is now being discussed for many commodities. Clearly, there will need to be incentives to farmers and marketing personnel to maintain the quality levels. The direct ties and even advance contracts between exporters and farmers are often a useful feature of developing these new markets and getting the exporters involved in input supplies as a start in the quality control process.

8. **Conclusions**

One indirect consequence of the concentration upon privatization and getting prices right is the neglect of public services, which had previously been directed at a broad spectrum of the society not just at the most productive regions. These services were often provided very inefficiently and sometimes even retarded the evolution of the private sector as with the public seed production system in Niger consistently underpricing seed and thereby preventing entry of private producers. This neglect of the public sector has also extended to critical public goods as research but even in the private sector it is necessary to move beyond a concentration on only the prime regions. With some support to public goods and clever design of incentives to the private sector other areas of agricultural production have substantial potential.

[8] For pigeon peas, the quality considerations include grain size, color, processing characteristics and quality control on the delivery to market. The need for quality seed production and for sufficient incentives for farmers are critical components of the successful introduction process (Jones et.al., 1999, pp. 19, 20). Another innovation was making the specialized exporters responsible for quality seed production.

Moreover, these areas are often where much of the low income sector in agriculture live.

Given the substantial potential of dryland agriculture with a little water harvesting and some inorganic fertilizer, the gloom-and-doom attitudes of the Sahel need to be relegated to history. Some of what Israel, Australia, much of Texas, Nebraska, and Kansas can do with more sunlight and less plant disease can also be done in the Sahel. Water retention and inorganic fertilizers are simple technologies. This is not nuclear science.

The keys to developing the drylands are the same as in the higher-rainfall regions and consist of two simple principles. Plants need nitrogen and phosphorus (and other major and minor nutrients). Farmers need to make money to adopt new technology. So get the Input and Product markets working for the drylands and the rest of the economy. The corollary here is to stop looking for magic or low-input solutions. None of the tricks or gimmicks provide sufficient plant nutrients. This includes manure, rock phosphate, intercropping of cereals and legumes, new cultivars alone, microrisa, and inoculation. So worry first about water and then inorganic fertilizer, where necessary, complemented with organic fertilizers. Identify the specific requirements to improve the functioning of the Input and Product markets for the dryland regions.

Developing the drylands is a major attack on rural poverty in Sub-Saharan African agriculture. But technology will not be able to resolve the problems of all the farmers. In regions where inorganic fertilizer does not become profitable with the removal of the subsidies and the improved functioning of Input and Product markets, there is not much that can be done in crop production Here we need to begin thinking of out-migration with the crop area ultimately to go into other activities such as forestry, agro-forestry, livestock production (Sanders et al. 1996, pp. 107-109).

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Libéralisation du marché céréalier au Burkina Faso: principaux résultats.

Boubié T. Bassolé

1 Introduction

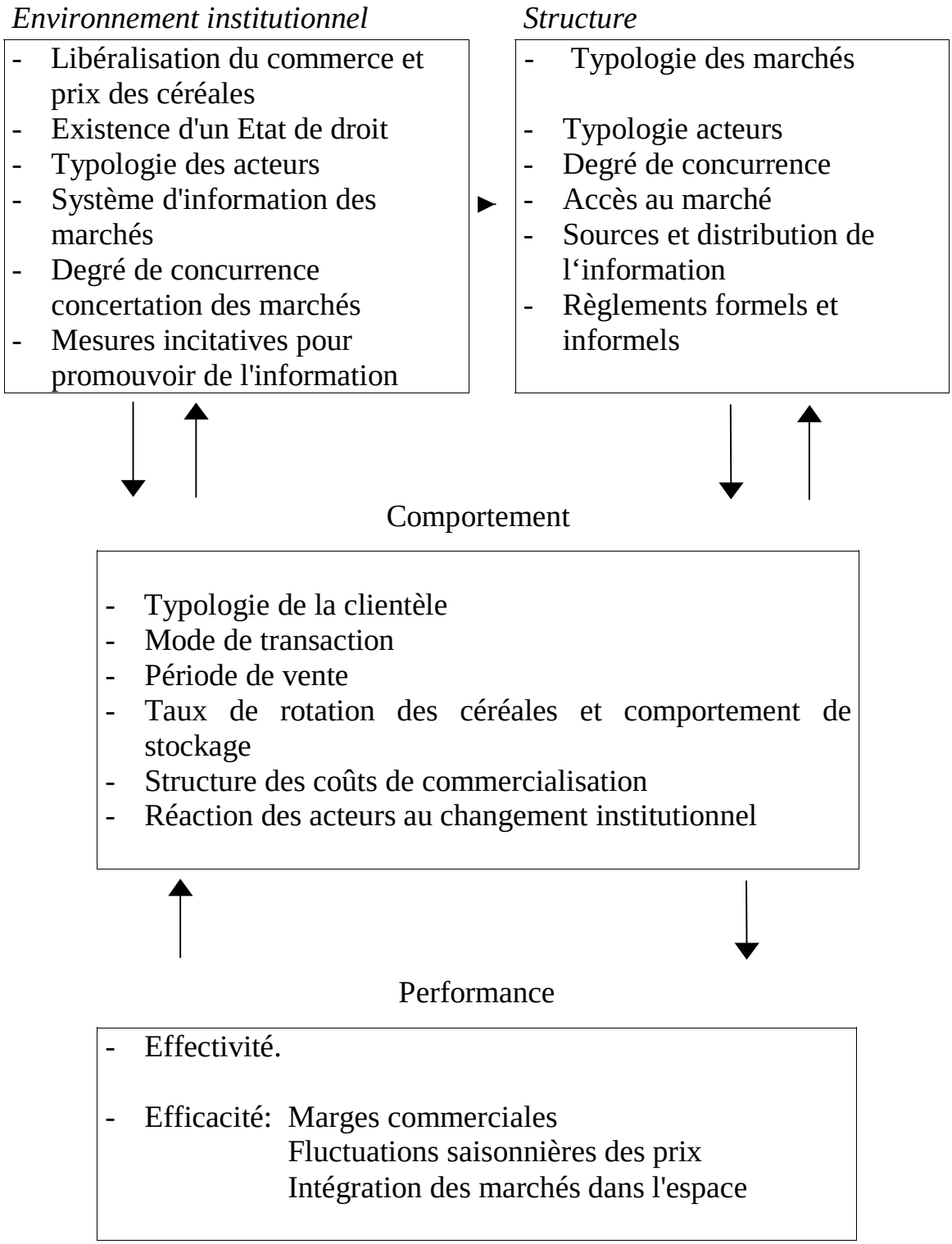
Au Burkina Faso, l'Etat s'est désengagé de la commercialisation des céréales depuis 1992. En plus de ce désengagement, il y a eu la libéralisation du commerce des céréales, de leur prix et la création d'un système d'information des marchés dans le but de rendre plus efficace l'organisation et l'efficacité économique des marchés céréaliers. Dès lors, il nous est apparu intéressant de chercher à répondre aux questions suivantes. La politique de libéralisation a-t-elle favorisé un accroissement de la concurrence de la structure du marché céréalier ? Les acteurs privés de la commercialisation des céréales ont-ils réagi favorablement à cet environnement avec des changements dans leur comportement et leur stratégie ? Quels sont les effets de l'évolution de la structure du marché et du comportement des acteurs céréaliers sur l'efficacité économique des marchés et plus exactement sur l'efficacité temporelle d'une part et l'efficacité spatiale de l'autre ?

L'objet de ce papier est de présenter les principaux résultats des effets de la libéralisation sur le marché céréalier. Il est structuré de la façon suivante. Dans la deuxième partie, nous exposons le cadre conceptuel et analytique de l'étude. Ensuite, nous présentons successivement les résultats relatifs aux effets de la libéralisation sur la structure du marché et le comportement des commerçants et des producteurs (troisième partie) et sur l'efficacité économique du marché (quatrième partie). En guise de conclusion, nous faisons quelques remarques terminales (cinquième partie).

2 Cadre conceptuel et analytique

Le cadre conceptuel auquel on se réfère pour apporter des éléments de réponse à la problématique de la recherche est celui de l'économie néo-institutionnelle et plus précisément de l'économie des coûts de transaction pour les raisons suivantes. La plupart des auteurs actuellement s'accordent sur le fait que pour analyser la performance d'un système économique et principalement dans les PVD, il faut faire appel à la nouvelle analyse économique institutionnelle ou économie néo-institutionnelle (voir par exemple, de Janvry, Sadoulet et Torbecke, 1994). En effet cette théorie semble avoir plus d'implications dans l'organisation économique à cause des phénomènes hors marchés qui se déroulent dans ces pays et pour le fait qu'il s'agit pour la plupart des pays en transition d'un régime dirigiste vers un régime libéral. En relation avec ce cadre conceptuel, l'approche analytique utilisée est une

Figure 1 : Relations entre les composantes du cadre analytique



synthèse des méthodes traditionnelles Structure-Comportement-Performance et de l'approche néo-institutionnelle avec cependant une place privilégiée de cette approche. Il s'agit alors de montrer comment l'environnement institutionnel influence la structure des marchés céréaliers, le comportement des acteurs (producteurs et commerçants)

et finalement la performance de la commercialisation. La figure 1 est une illustration de ces relations.
Deux types de données ont été utilisées pour estimer les effets de la libéralisation. Ce sont des données primaires et des données secondaires. Les données primaires ont concerné la structure du marché céréalier, le comportement et la stratégie des commerçants et des producteurs, et les coûts de commercialisation. Ces données ont servi à apprécier l'évolution de la structure des marchés, la réaction des commerçants et des producteurs dans cet environnement libéral et l'estimation des marges commerciales. Quant aux données secondaires, elles sont relatives aux séries des prix des céréales et elles ont été utilisées pour estimer l'efficacité temporelle et spatiale du commerce des céréales.

3 Environnement libéral, structure du marché céréalier et comportement des acteurs

3.1 Environnement libéral et structure du marché céréalier

Les céréales sont actuellement commercialisées au Burkina Faso dans un contexte caractérisé par un Etat de droit qui met les agents économiques en condition de s'exprimer librement sur les marchés. Théoriquement, cet environnement respecte et sécurise légalement les droits de propriété des acteurs (producteurs et commerçants). Par ailleurs, l'existence d'institutions formelles et informelles liées à la commercialisation des céréales comme le Système d'information du marché céréalier (SIM) contribue à stimuler et à dynamiser les échanges commerciaux de céréales entre ces acteurs. Selon les enseignements de l'économie néo-institutionnelle, ce contexte est supposé favoriser l'existence d'une structure plus concurrentielle. Il s'agit alors de tester cette hypothèse.

Les résultats obtenus à partir de l'analyse des données primaires ont fait ressortir les éléments suivants. L'évolution de la structure du marché céréalier, telle qu'elle apparaît selon les informations recueillies sur certains éléments comme la typologie des marchés et des acteurs, le libre accès, les sources et la distribution de l'information, les opinions des commerçants et des producteurs, laisse penser à un développement de la concurrence. En effet, l'entrée de nouveaux acteurs (commerçants privés, institution de commercialisation des céréales) sur le marché céréalier a eu pour conséquence une augmentation globale du nombre d'intermédiaires. Ceci a accentué la concurrence. Le développement de cette concurrence a entraîné, avec l'effet des récoltes, une meilleure

rémunération des producteurs et principalement ceux des zones excédentaires. Enfin l'existence d'un système d'information des marchés a contribué à rendre le marché céréalier plus transparent car ce système selon les informations recueillies auprès de certains commerçants leur permet de choisir leurs marchés d'approvisionnement en fonction des prix des céréales. Il convient de noter cependant que la concurrence du marché céréalier est entravée par certaines difficultés révélées par les commerçants.

Il s'agit du faible financement des activités de la commercialisation des céréales par les banques, du coût élevé de la patente, de l'instauration de taxes injustifiées, de mauvais état de l'infrastructure routière, de l'irrégularité de la diffusion des prix des céréales et surtout de la fiabilité de l'information relative à ces prix. En effet le constat est que le SIM assure avec beaucoup de difficultés ces différentes tâches. Cette déficience semble s'expliquer par des problèmes d'ordre institutionnel et administratif que l'on peut résumer en deux points.

Tout d'abord il y a eu des problèmes conjoncturels qui sont relatifs à la restructuration et à la liquidation de l'Office national de la commercialisation des céréales (OFNACER) et précisément au départ des agents de sa cellule d'Etude, de Planification et de Statistique avec qui le système d'information a été élaboré et mis en place et celui des magasiniers qui étaient chargés de la collecte des prix sur les marchés13. Ces événements conjoncturels ont eu des répercussions négatives sur le fonctionnement de l'institution.

Ensuite on peut mentionner des problèmes structurels qui concernent la transmission à de l'information collectée sur les différents marchés au siège du SIM à Ouagadougou pour sa saisie, son traitement et sa diffusion. Pour la transmission, l'information sur les prix collectée dans les grandes villes, est transférée par télécopie à Ouagadougou. Mais dans les zones rurales le transfert de cette information est basé sur le recours des transporteurs routiers. Cette forme de transfert peut être source de perte ou de retard. Quant aux tâches de saisie et de traitement, elles sont exécutées par un seul agent.

Ces difficultés institutionnelles illustrent le fait que souvent dans les pays en transition, des réformes économiques sont mises en œuvre avant que les changements institutionnels nécessaires soient effectifs. En effet le SIM a été créé dans un contexte de réformes (liquidation de

[13] Environ 300 agents de l'OFNACER ont été licenciés à la suite de sa liquidation.

l'OFNACER, libéralisation du commerce et des prix des céréales) mais des mesures adéquates (personnel qualifié, ressources matérielles) n'ont pas accompagnées sa création pour permettre à cette institution de réaliser efficacement ces objectifs. Cette inadéquation illustre l'inertie de cette structure. Cette forme d'inertie institutionnelle a été mise en évidence par certaines études sur la transition dans les pays de l'Est.

3.2 Environnement libéral et comportement des acteurs du commerce des céréales

3.2.1 Environnement libéral et comportement des producteurs.

L'idée générale est que les producteurs dans les pays africains concentrent leur vente immédiatement après les récoltes et ne profitent pas de la hausse des prix des céréales pendant les mois de soudure. Par exemple Dejou (1987, p. 128) indique pour le cas du Burkina Faso que le comportement de la majorité des producteurs constituée par des petits et moyens producteurs est de concentrer leur vente pendant la période d'octobre à décembre au moment des récoltes. Les résultats des enquêtes confirment-ils ce comportement ? L'environnement libéral a-t-il influencé le comportement des acteurs (commerçants et producteurs) du commerce des céréales ? Les résultats obtenus montrent que l'environnement libéral a eu une influence sur le comportement des producteurs notamment ceux des zones excédentaires. Ces producteurs semblent passés d'un comportement passif à un comportement actif dans la vente de leurs céréales. En effet, non seulement ils planifient cette vente dans le temps pour bénéficier de la hausse saisonnière des prix, mais ils préfèrent vendre aussi au plus offrant. De même en bénéficiant de l'encadrement de certaines institutions qui sont impliquées dans le commerce des céréales, ils diversifient leurs partenaires commerciaux.

3.2.2 Environnement libéral et comportement de stockage des commerçants

Le stockage des céréales et notamment celui de longue durée par les commerçants est l'une des stratégies que ceux-ci peuvent développer dans l'objectif de maximiser leur profit. Ainsi ils achèteront de grandes quantités de céréales au moment des récoltes où les prix sont faibles et vendre une grande partie de leurs stocks au moment où les prix sont élevés en période de soudure.

Dans le passé et précisément durant la période révolutionnaire les commerçants étaient qualifiés de véreux et de spéculateurs qui exploitaient les producteurs et les consommateurs. Cet environnement

hostile défavorisait le stockage car les commerçants dans la crainte d'une saisie de leurs stocks par les autorités préféraient avoir une rotation rapide de leurs céréales. Dans le contexte de l'Etat de droit et de la libéralisation du commerce où les droits de propriété privée sont garantis, on peut supposer que cet environnement incite les commerçants à stocker leurs céréales pendant une période relativement longue. C'est cette hypothèse que l'on cherche à tester grâce aux résultats des enquêtes

Les résultats obtenus révèlent que l'environnement institutionnel n'a pas véritablement changé le comportement de stockage des grossistes et des semi-grossistes. En effet la durée moyenne de stockage de la majorité des répondants n'excède pas trois mois. La conservation des céréales au cours du temps par les commerçants pour bénéficier d'une éventuelle hausse des prix pendant la période de soudure ne semble pas être une stratégie de maximisation des profits de ces commerçants. Ceux-ci préfèrent plutôt une rotation rapide de leurs grains pour les raisons suivantes. La première raison invoquée est l'insuffisance du capital financier (fonds de roulement) pour l'achat de grandes quantités de céréales au moment des récoltes et les difficultés de conservation des stocks. La troisième raison du comportement de la faible durée de stockage de la majorité des grossistes et des semi-grossistes que ceux-ci n'ont pas révélée se trouve dans la rotation technique d'une partie de stock de sécurité de la société nationale de la gestion du stock de sécurité alimentaire (SONAGESS). En effet pour renouveler son stock de sécurité, la SONAGESS procède annuellement à un déstockage d'une partie de ces céréales. Ce déstockage ou rotation technique a lieu au moment de la soudure (juin, juillet et août) sur appel d'offre. Ce déstockage entraîne également un accroissement de céréales pendant cette période. Aussi tenant compte de tous ces facteurs et de leurs effets sur le niveau des prix pendant la soudure, la majorité des grossistes et des semi-grossistes préfère-t-elle éviter le stockage de longue durée. Cette politique de l'offre de céréales par l'Etat qui ne favorise pas le stockage de longue durée est également incompatible (contradictoire) avec la mesure d'incitation de l'octroi du crédit aux commerçants céréaliers que le gouvernement veut promouvoir.

3.2.3 Les coûts de commercialisation

La partie relative au comportement de stockage des commerçants a révélé que la durée moyenne de stockage de la majorité des répondants n'excède pas trois mois. Cette stratégie est plutôt basée sur une rotation rapide de leurs grains et elle a pour conséquence d'augmenter la fréquence d'achats des céréales dans les zones d'approvisionnement.

On peut donc admettre que cette fréquence contribue à maintenir des coûts de commercialisation plus élevés notamment les coûts de transaction. Le tableau 1 met en évidence la répartition des coûts de transaction et de transformation dans l'ensemble des coûts de commercialisation liés aux échanges commerciaux des céréales selon les différents commerçants[14].

Tableau 1: Répartition de coûts de commercialisation d'un sac de 100 kilogrammes de céréales

	Grossiste de Solenzo		**Grossiste de Sankariaré**		**Semi-grossiste de Sankariaré**		**Grossiste de Dori**		**Grossiste de Ouahigouya**	
Structure du coût	**Montant**	**%**	**Montant**	**%**	**Montant**	**%**	**Montant**	**%**	**Montant**	**%**
Coût de transformation	131	33	166	15	165	16	483	37	523	32
Coût de transaction	262	67	911	85	851	84	817	63	1088	68
Coût total de commerciali–sation	393	100	1077	100	1016	100	1300	100	1611	100

Source : calculs effectués à partir des données d'enquête

Ce tableau synthétique fait ressortir que la part des coûts de transaction est relativement prépondérante dans l'ensemble des coûts de commercialisation quelle que soit la distance du commerce (commerce intra-régional ou commerce inter-régional). En effet cette catégorie de coûts représente en moyenne plus de 60% des coûts de commercialisation. La forte proportion de ces coûts est principalement due au coût de transport des céréales. Ceci confirme l'une des difficultés de la commercialisation des céréales révélées par certains commerçants à savoir «le coût élevé des transports dû au mauvais état des routes ». Cependant il convient de noter que le niveau du coût du transport peut également être imputé aux divers circuits de commercialisation que les commerçants suivent dans leurs opérations.

En effet le commerçant grossiste ou semi-grossiste n'a pas un seul marché d'approvisionnement mais il se déplace sur plusieurs marchés

[14] Le coûts de transformation sont liés aux coûts engendrés par la valeur ajoutée au produit. Pour les céréales au Burkina, il s'agit essentiellement des coûts de stockage (coûts d'entreposage et coûts finaciers). Les coûts de transaction sont les coûts engendrés au moment de la transaction lorsqu'un individu transfère le droit de propriété qu'il détient sur un bien dans un cadre marchand. Il s'agit des coûts de transport, de la manutention, des taxes de commercialisation des céréales, etc.

pour satisfaire sa demande des céréales. Cette ronde des commerçants à la recherche des céréales s'explique principalement par l'incomplétude et l'imperfection de l'information qu'ils détiennent du marché céréalier. Cette information incomplète et asymétrique contribue par conséquent à augmenter les coûts de transport moyens supportés par le commerçant pour le transfert des céréales. Ces résultats créditent la vision néo-institutionnelle selon laquelle dans les pays en développement où les transactions sont incertaines et risquées à cause d'une information asymétrique et imparfaite, les coûts de transaction sont plus élevés et les dysfonctionnements des marchés plus fréquents.

4 Efficacité libérale et efficacité économique des marchés

4.1 Environnement libéral et efficacité temporelle des marchés céréaliers

L'efficacité temporelle des marchés ou efficacité saisonnière des prix est l'un des indicateurs de l'efficacité économique des marchés. L'étude de l'efficacité temporelle des marchés a pour objectif d'analyser les variations intra-annuelles des prix des céréales par rapport au coût de stockage afin de déterminer si les marchés apparaissent spéculatifs au moment de la soudure. En effet, dans un pays comme le Burkina Faso, les récoltes ont lieu une fois dans l'année au cours de trois mois (octobre à décembre) avec une période de soudure qui s'étale de juillet à août. Ces caractéristiques saisonnières entraînent alors des fluctuations des prix au cours de l'année.

Par rapport au comportement des acteurs, ces enquêtes ont révélé que la grande majorité des commerçants ne stocke pas au-delà d'une durée de trois mois et qu'une forte proportion des producteurs étale dans l'année leur commercialisation des céréales. Ce comportement novateur de la vente des céréales par les producteurs suppose qu'ils contribuent avec les commerçants à assurer les opérations d'arbitrage inter-temporel. Il est donc important de déterminer la relation entre les variations saisonnières des prix des céréales et les résultats des enquêtes sur l'évolution des marchés et sur le comportement des commerçants et des producteurs.

4.1.1L'évolution des prix des céréales

Le tableau 2 donne un aperçu de l'évolution des prix du sorgho au consommateur et les coefficients de variation de ces prix sur chaque marché (voir également graphiques 1a à 8a). Ces prix sont des

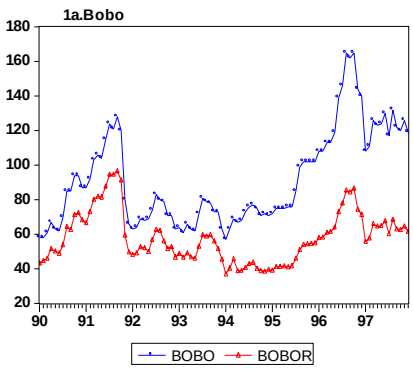
moyennes pour l'année calculées à partir des fréquences mensuelles des données

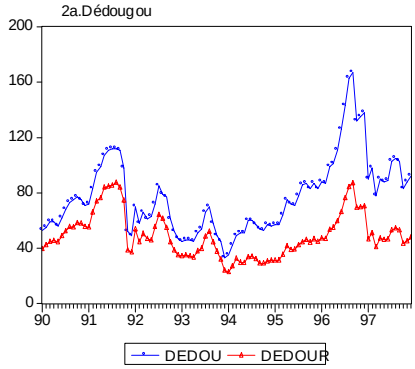
Tableau 2: Prix moyens (FCFA/KG) au consommateur en terme réel du sorgho et leur instabilité

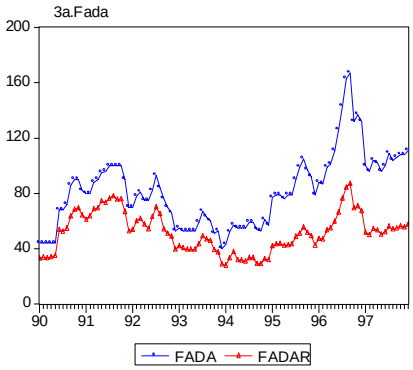
	Bobo	Dédou	Fada	Kaya	Koudo	Ouaga	Ouahi	Pouy
1990	47	43	49	60	52	61	58	50
cv	0,13	0,11	0,25	0,13	0,10	0,08	0,05	0,14
1991	72	64	67	74	73	82	78	65
cv	0,10	0,24	0,10	0,22	0,17	0,13	0,25	0,20
1992	48	50	53	55	58	63	48	57
cv	0,12	0,20	0,14	0,10	0,06	0,05	0,11	0,11
1993	46	32	38	46	48	55	44	46
cv	0,12	0,17	0,15	0,05	0,12	0,06	0,10	0,09
1994	31	25	30	39	34	41	34	36
cv	0,08	0,10	0,08	0,09	0,06	0,07	0,12	0,07
1995	39	32	41	42	41	46	43	43
cv	0,21	0,16	0,17	0,07	0,14	0,09	0,12	0,23
1996	61	57	54	71	67	68	69	64
cv	0,17	0,21	0,17	0,19	0,15	0,15	0,18	0,14
1997	58	45	55	61	53	62	55	59
cv	0,05	0,08	0,08	0,09	0,03	0,06	0,04	0,07

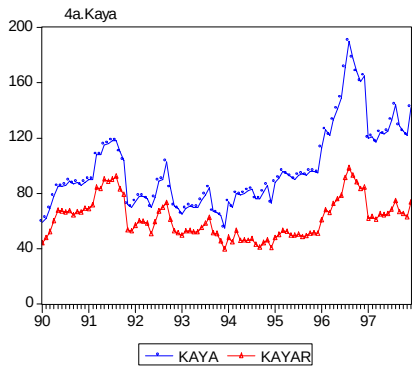
Note: Les prix sont des moyennes pour l'année.
cv = coefficient de variation = écart-type/moyenne
Dédou = Dédougou; Koudo = Koudougou; Ouahi = Ouahigouya; Pouy = Pouytenga, Bobo=Bobo-Dioulasso
Source: Calculs effectués à partir des données mensuelles du SIM.

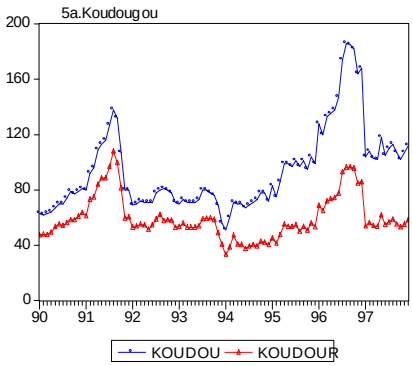
Graphiques 1a à 8a: Evolution des prix à la consommation en termes réel et nominal du sorgho sur les principaux marchés

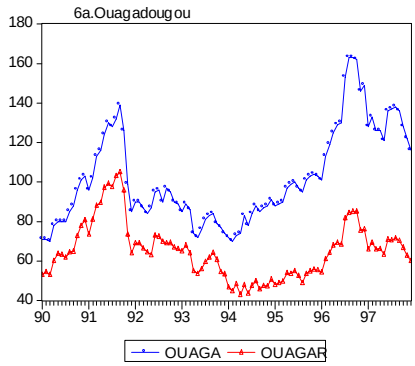


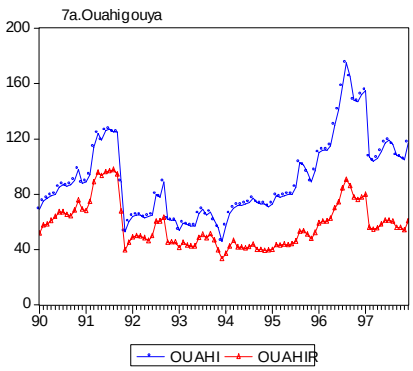


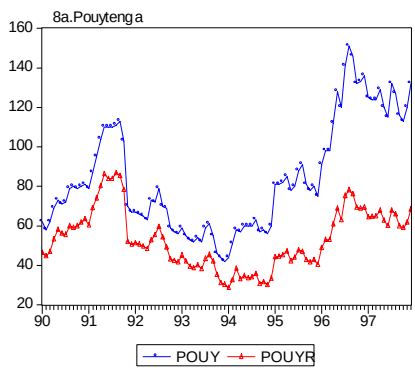












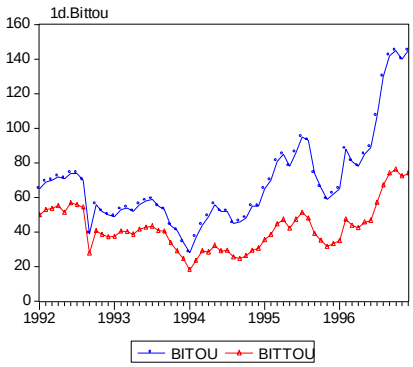
Si l'on considère maintenant les prix au producteur, le tableau 3 et les graphiques (1b à 7b) montrent comment ces prix ont évolué au cours de la période 1992-1996.

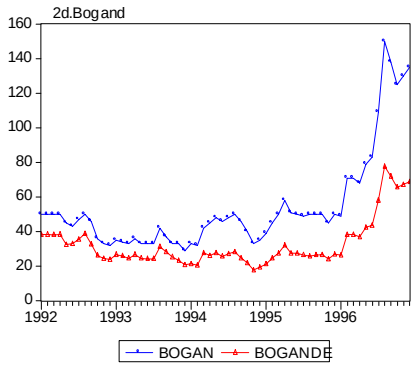
Tableau 3: Prix moyens (FCFA/KG) au producteur en terme réel du sorgho et leur instabilité

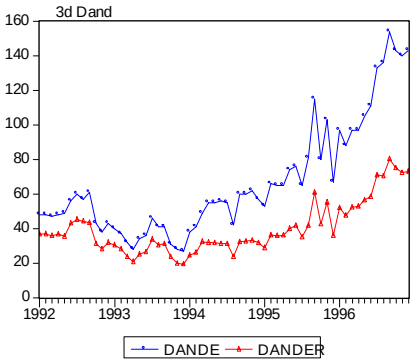
	Bittou	**Bogand**	**Dandé**	**Djibas**	**Fada**	**Pouy**	**Solenz**
1992	48	44	37	40	57	52	34
cv	0,20	0,12	0,15	0,16	0,15	0,09	0,24
1993	38	26	26	32	34	44	25 s
cv	0,15	0,10	0,18	0,15	0,15	0,09	0,18
1994	27	25	18	24	26	33	18
cv	0,14	0,13	0,10	0,15	0,10	0,08	0,15
1995	42	26	29	31	40	44	25
cv	0,14	0,10	0,11	0,11	0,10	0,05	0,14
1996	50	46	48	55	58	61	43
cv	0,20	0,28	0,18	0,18	0,16	0,14	0,19

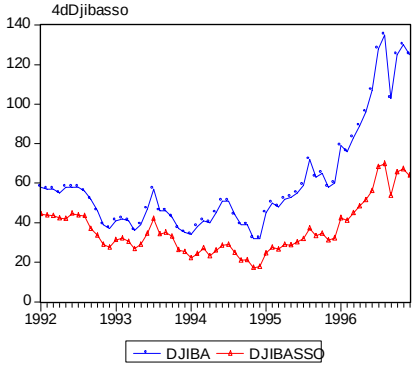
Note: Les prix sont les moyennes de l'année.
n.d. = données non disponibles.
cv = coefficient de variation = écart-type/moyenne.
Bogand= Bogandé; Djibas= Djibasso; N'Dor= N'Dorola;
Pouy= Pouytenga; Solenz= Solenzo.
Source: Calculs effectués à partir des données mensuelles du SIM.

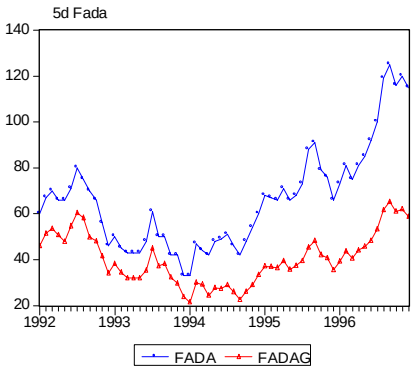
Graphiques 1b à 8b: Evolution des prix au producteur en termes nominal et réel du sorgho sur les principaux marchés

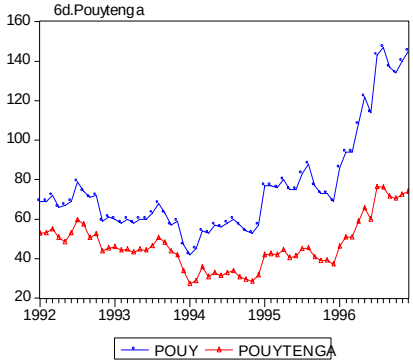


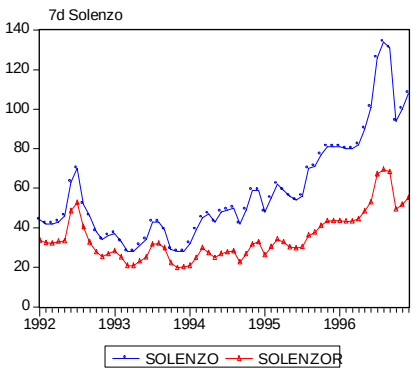












L’analyse de l’évolution des prix des céréales dans le temps révèle une forte augmentation des prix au producteur et consommateur après la libéralisation du marché céréalier. L’un des facteurs explicatifs de cette augmentation est le changement structurel de la demande des céréales (accroissement de la demande globale des céréales) par rapport à une offre en régression. L’accroissement de la demande globale est dû à la demande d’importation des pays frontaliers et à celle des consommateurs locaux. Mais dans la même période, l’offre des céréales a stagné, voire diminuée.

4.1.2Les variations saisonnières des prix et les coûts de stockage

Pour un produit stockable et dont la production a lieu pendant une période déterminée de l’année, les différences des prix entre la récolte et la soudure devraient être égales au coût de stockage si les marchés sont concurrentiels (Goetz et Weber, 1986, Azam et al. 1992). L’estimation de la rentabilité nette du stockage (comparaison de la différence des prix entre deux périodes au coût de stockage) permet de conclure si les marchés sont spéculatifs (faible concurrence) ou si la saisonnalité des prix est forte. En suivant Armah (1989, p. 268) on peut estimer la rentabilité nette du stockage de la façon suivante. Dans un premier temps, on détermine l’écart de l’indice saisonnier c’est-à-dire la différence entre le niveau le plus élevé et celui et plus faible de l’indice de saisonnalité. Cet écart est ensuite exprimé en variation totale par rapport à l’indice le plus faible. Enfin, on calcule l’augmentation mensuelle de l’indice de saisonnalité qui est le rapport entre la variation totale et le délai moyen (i-e le nombre de mois entre l’indice de saisonnalité le plus élevé et le plus faible). Le tableau 4 indique la rentabilité nette du stockage.

Tableau 4: Ecart et augmentation mensuelle en moyenne des indices saisonniers des prix au consommateur pour le sorgho

	Bobo	Dédou	Fada	Kaya	Koudou	Ouaga	Ouahi	Pouy
Janvier	0,856	0,833	0,892	0,937	0,894	0,925	0,879	0,968
Février	0,891	0,896	0,909	0,952	0,930	0,947	0,970	0,979
Mars	1,017	0,982	0,995	1,010	0,990	0,997	1,000	1,023
Avril	0,952	0,950	0,993	1,007	1,026	0,985	1,016	1,019
Mai	0,995	1,040	0,966	1,020	0,982	1,003	1,022	0,998
Juin	1,072	1,0934	1,010	1,033	1,046	1,031	1,050	1,006
Juillet	1,112	1,198	1,106	1,119	1,098	1,037	1,124	1,095
Août	1,164	1,214	1,138	1,151	1,088	1,053	1,120	1,189
Septembre	1,098	1,119	1,110	1,031	1,082	1,068	1,094	1,047
Octobre	1,041	0,979	1,072	0,992	1,001	1,063	0,982	0,963
Novembre	0,948	0,916	1,002	0,908	0,948	0,943	0,890	0,880
Décembre	0,905	0,863	0,852	0,874	0,940	0,960	0,895	0,909

Source: Calculs effectués à partir des données mensuelles du SIM .

Il ressort de ce tableau que la comparaison entre l'augmentation annuelle en moyenne de l'indice de saisonnalité et le coût du stockage montre que cet indice est inférieur au coût de stockage. Autrement dit l'accroissement saisonnier des prix ne couvre pas le coût du stockage. L'arbitrage dans le temps n'est pas dû uniquement aux opérations d'arbitrage des commerçants mais aussi à celles de certains acteurs et institutions comme les producteurs et la SONAGESS. Ce résultat n'apporte pas de crédit au sentiment selon lesquels les commerçants sont des spéculateurs et des exploiteurs des consommateurs et des producteurs. Ces fluctuations saisonnières ne permettent donc pas de suspecter une rentabilité démesurée provenant de la constitution des stocks de céréales pour la commercialisation et ce dans la plupart des régions.

5 Environnement libéral et efficacité spatiale du marché céréalier

L'efficacité spatiale ou l'efficacité de l'intégration spatiale de la commercialisation des céréales étudie le fonctionnement des marchés dans l'espace. L'objectif de l'intégration spatiale des marchés est d'évaluer le fonctionnement des échanges commerciaux des céréales entre des paires de marchés – en l'occurrence entre marchés excédentaires et marchés déficitaires - en déterminant si les différentiels des prix entre ces paires de marchés reflètent les coûts de transferts des échanges. L'efficacité spatiale des marchés est donc fonction du degré d'interdépendance des prix et dépend de la liberté du commerce, de la qualité de l'information sur les conditions des marchés et par conséquent de l'étendue de la vitesse avec laquelle les prix sont transmis d'un marché à un autre. Pour appliquer les tests de la cointégration dans notre étude, on a distingué des sous-périodes appropriées prenant en compte les réformes économiques relatives au marché céréalier. Ces sous-périodes sont ceux de la pré-libéralisation (1990-1992) et de la post-libéralisation (1993-1998). Les tests de la cointégration des séries de prix des différents marchés sont appliqués à chaque sous-période dans un premier temps. Dans un second temps, on compare les résultats d'estimation de cointégration entre la période pré-libéralisation et celle de la post-libéralisation. Aussi un accroissement des relations de cointégration de la sous-période de la post-libéralisation peut-il être considéré comme une preuve statistique de l'amélioration du fonctionnement des marchés et donc de leur efficacité spatiale grâce à la politique de la libéralisation.
Les tests de cointégration des séries des prix des huit marchés pour les trois périodes et les valeurs critiques du rapport (ratio) de vraisemblance associées aux tests de la valeur propre sont reportées dans le suivant selon la procédure de Johansen (1988)[15].

[15] Il convient de signaler au lecteur qu'avant d'appliquer la procédure de Johansen, on a effectué un test de la stationnarité des prix (Dickey-Fuller).

Tableau 5: Tests de cointégration de Johansen (sorgho)

Rapport de vraisemblance			Valeurs critiques		Hypothèse sur le Nombre de E.C
1990-1992	**1993-1998**	**1990-1998**	**5%**	**1%**	
224,33**	304,71**	355,11**	170,80	182,51	Aucune
160,38**	225,81**	255,06**	136,61	146,99	Au plus 1
104,15	155,26**	176,81**	104,94	114,36	Au plus 2
62,99	92,91**	106,61**	77,74	85,78	Au plus 3
40,37	52,72	63,81**	54,64	61,24	Au plus 4
25,01	27,86	34,57*	34,55	40,49	Au plus 5
11,54	15,96	13,99	18,17	23,46	Au plus 6
4,73	4,84	4,87	3,74	6,40	Au plus 7

Notes: E.C= Equation de cointégration.
**(**) dénote l'hypothèse sur le nombre de relations de cointégration à un niveau de significance de 5%(1%)*
Les valeurs critiques sont données par Eviews 3

Les résultats de ce tableau montre un nombre de relations de cointégration de la période post-libéralisation supérieur à celui de la période pré-libéralisation. L'augmentation du nombre de relations de cointégration suggère alors que les prix des céréales sont étroitement plus reliés pendant la période de libéralisation. Ceci indique alors que le degré de stabilité de long terme des relations des prix des céréales au cours de cette période est devenu plus intense. Cette intensité peut s'expliquer par l'applications de certaines mesures telles que la diffusion de l'information sur les prix et la levée de certaines entraves relatives aux échanges inter-régionaux des céréales.

6. Remarques terminales

La présente étude a présenté les résultats relatifs aux effets de la libéralisation sur l'organisation de la commercialisation des céréales et l'efficacité économique du marché céréalier au Burkina Faso. De façon générale les mesures ont été effectives dans leur application et elles ont eu pour effet une amélioration de l'efficacité de l'organisation et de la performance de la commercialisation des céréales. Il reste cependant que pour renforcer cette performance et la sécurité alimentaire, les décideurs de la politique économique notamment de la politique céréalière sont invités à jouer ou à accroître leur rôle dans les domaines suivants : promotion de la concurrence, augmentation du stockage commercial et création des opportunités du marché céréalier.

La promotion de la concurrence

La promotion de la concurrence des marchés céréaliers nécessite une plus grande transparence de l'information, une garantie de la liberté pour les acteurs de transférer librement leurs droits de propriété et leur sécurisation. Il est indispensable que le système d'information des marchés céréaliers, véritable instrument de la transparence du marché soit plus opérationnel dans son rôle d'éclairer les opérateurs économiques dans leur prise de décision. A cette fin, il est recommandé aux dirigeants du système d'information de diversifier les supports pour permettre une large diffusion de l'information. A ce titre, en plus de la radio nationale, les radios privés décentralisés et les journaux en langue nationale peuvent servir de supports.

D'autre part, la seule collecte des prix ne suffisant pas pour favoriser l'adaptation de l'offre en fonction de la demande, il est souhaitable qu'à moyen terme le système d'information des marchés puisse envisager la collecte et la diffusion des quantités de céréales et principalement dans les marchés primaires des régions excédentaires et dans les marchés de regroupement (Bobo-Dioulasso et Pouytenga) qui sont les marchés d'achat de la majorité des commerçants. La disponibilité de cette information peut contribuer non seulement à réduire les la ronde des commerçants à la recherche des céréales et par conséquent leurs coûts de transactions mais aussi les oligopoles des grands commerçants qui disposent de leur propre service d'information grâce auquel ils s'assurent des données du marché céréalier et donc un avantage face à la concurrence.

L’augmentation du stockage commercial et la création d’opportunités pour le marché céréalier

L'augmentation du stockage commercial et la création d'opportunités pour le marché céréalier sont également recommandées. Pour cela, le rôle actuel du stock national de sécurité doit être revu. En effet, le déstockage ou la rotation technique du stock national de sécurité par la SONAGESS qui a lieu pendant la période de soudure (juin, juillet et août) empêche une hausse importante des prix des céréales mais a pour corollaire une réduction des quantités stockées par les commerçants. Ce déstockage qui s'apparente à une forme déguisée de l'Etat sur le marché est préjudiciable au commerçant qui n'a aucun intérêt à stocker une partie importante de céréales pour la soudure étant donné que l'accroissement des prix pendant cette période ne couvre pas le coût de stockage de longue durée. Il faut alors rechercher une harmonie entre l'intervention de la SONAGESS et le commerce privé. Cette harmonie

consiste à ce que le stock de la rotation technique de la SONAGESS serve essentiellement à assurer la sécurité alimentaire des populations dans les zones rurales déficitaires et à risques alimentaires où le pouvoir d'achat est faible. Dans ces conditions, une partie de ce stock peut être vendue à un prix social aux banques de céréales et à d'autres structures comme le comité national des secours d'urgence (CONASUR) et le programme de sécurité alimentaire et nutritionnelle (PSAN). Etant donnée que la demande des céréales sur le marché de cette catégorie de population est marginale, le marché céréalier ne sera pas perturbé pendant la soudure. Cette action de la SONAGESS peut alors inciter les commerçants à constituer un stockage commercial. Dans ces conditions, l'octroi du crédit aux commerçants des céréales pour les inciter à s'impliquer davantage dans le marché céréalier est opportun. Aussi pour faciliter l'accès de ce crédit à la grande majorité des commerçants, est-il souhaitable de recourir à un système de crédit adapté. A ce titre, les institutions financières décentralisées qui couvrent l'ensemble du territoire et dont les procédures de financement sont relativement moins contraignantes peuvent jouer un rôle important dans ce financement.

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If the River bends, the Crocodile will bend too

Some Results of an Analysis of Farming Systems in the North-Western Region of Burkina Faso

Arno Maatman

"Crisis narratives are the primary means whereby development experts and the institutions for which they work claim the right to stewardship over land and resources they do not own. By generating and appealing crisis narratives, technical experts and managers assert rights as 'stakeholders' in the land resources they say are under crisis"(Roe, 1995: 1066).

1. Introduction

This paper will give a short overview of an extensive study that was executed in the north-western region of Burkina Faso[16] (see map 1). The objective of this study was to analyse the perspectives of sustainable intensification of farming systems, through low cost technologies. The following questions were asked: to what extent can the actual strategies of the farmers guarantee food security of their households? what changes are possible to ensure a higher and sustainable level of food security? what are possible governmental and non-governmental interventions which could encourage and maintain such changes? The study was limited to the sedentary farmers in the north-western region. Mathematical programming models were used as an instrument of analysis.

In this paper we will focus on the results[17]. However, enough attention will be given to the methodological approach, which in some way can be considered a result in itself (sections 3 and 4). While discussing the results we will first focus on the more or less 'traditional' decisions with respect to the production, the storage and the marketing of agricultural (read vegetable) products (section 5). Heterogeneous and flexible farmer's strategies are shown to be the result of risk minimising and labour optimising objectives. Next, we will concentrate on 'new' methods of water and soil conservation (even though they are often based on traditional knowledge) and on the integration of agriculture and livestock (sections 6). These strategies, based on low cost technologies, are being adopted by many farmers in the region; in particular in the more densely populated areas where the problem of soil degradation is most severely felt. It is demonstrated that these strategies improve, at least in the short run, agricultural productivity and food security. The longer-term perspectives of the rural populations in the north-western region are discussed in section 7. Despite some evident problems, the 'doom scenarios' are to be rejected. Farming systems are less vulnerable than often thought, and rural populations have a long history of creative 'adaptation'. Government policies and development programs should – therefore – be carefully designed and implemented. 'Enabling' policies and projects with a flexible and mutual learning approach seem to be – for the time being – the most efficient. Finally we

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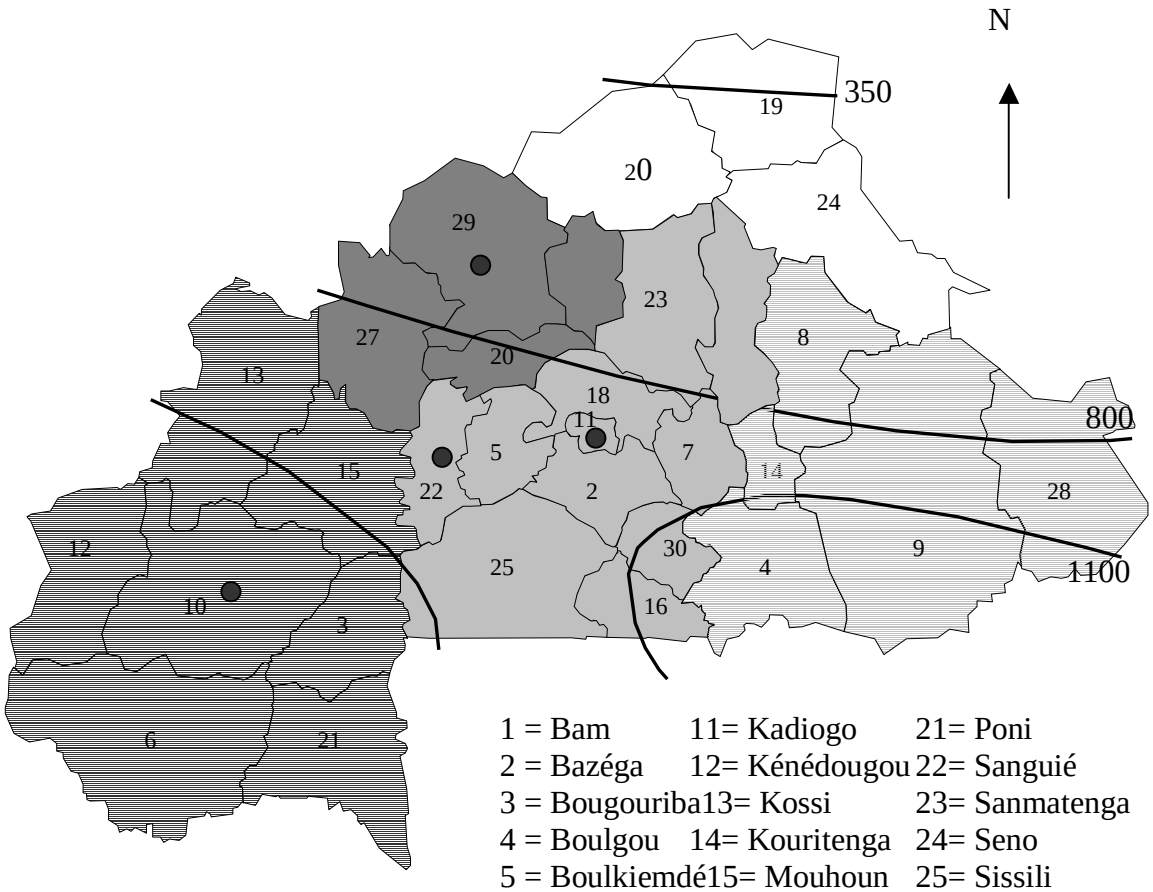
For a detailed description of this study see Maatman (2000).
This paper draws heavily from the summary in Maatman (2000).

will say a last word on the methodological approach (section 9). In the next section we will first discuss the context of the study.



Région

Région Centrale

Région

Région Nord-

Région

1 = Bam 11= Kadiogo 21= Poni
2 = Bazéga 12= Kénédougou 22= Sanguié
3 = Bougouriba 13= Kossi 23= Sanmatenga
4 = Boulgou 14= Kouritenga 24= Seno
5 = Boulkiemdé 15= Mouhoun 25= Sissili
6 = Comoé 16= Nahouri 26= Soum
7 = Ganzourgou 17=Namentenga 27= Sourou
8 = Gnagna 18= Oubritenga 28= Tapoa
9 = Gourma 19= Oudalan 29=Yatenga
10= Houet 20= Passoré 30= Zoundwéogo

Grandes villes
Ouagadougou (province du Kadiogo) – capital

Map 1: Burkina Faso

2. Context of the study

Burkina Faso is one of the rare countries in West Africa where agricultural production increased considerably after the drought years in the early 70s and 80s; the cereal production has exceeded – even if

only marginally – the population growth between 1985 and 1995. It is also one of the few countries where the 'external' debts increased very moderately between the 80s and the 90s, giving the government a favourable position in the negotiations with the 'Bretton Woods' institutions. Despite these performances, Burkina Faso is still one of the poorest countries in the world. The north-western region covers about 11% of the national territory (31.000 km^2). It comprises 4 provinces (Bam, Passoré, Sourou, Yatenga) and 1,4 million inhabitants of various ethnic groups. Demographic density varies considerably from one sub-region to another. The majority of the population mainly lives from agriculture. The region comprises pastoralists, agro-pastoralists and sedentary farmers; irrigated agriculture is practised in the Sourou valley. It is noted that most villages in the north-western region are located at quite some distance from the larger market-places and the principal roads. Besides, the whole region has only one paved road that goes from Ouagadougou to Ouahigouya, the capital of the Yatenga province. The sedentary farmers in the region produce to a large extend just to fulfil their own consumption needs; only a small part of their production is sold. Local food markets are 'thin' and the supply varies much from one period to another. Agricultural production is based on the cultivation of millet and sorghum, often associated with cowpeas. Maize is also grown, on some small plots around the dwellings. A study on the dynamics of agrarian systems in two village-sites in the North-Western region (Baszaïdo and Lankoé, see below) demonstrated, among others, the tremendous extension of the agricultural area (in terms of hectares per active member!) in the last decades (see also Dao *et al.*, 1996 a,b). These strategies, based on the 'extensification' of land-use practices, seem to reach – at least in a large part of the north-western region – their limits[18]. As one young farmer in another study village in the north-western region said:

"We know very well that we can not continue cultivating more and more fields, as we have done for a long time. But what can we do, if we only have some few fields, which are often located at quite some distance from each other? And if we have to share these already small areas with again more people in the future? This is difficult already, but it is not all, far from that. The work on the field has become more arduous than before, even in the words of our parents. Many of us are afraid to start cultivating, knowing that it will be very difficult to feed our families from the fields we have and our own labour. Some of us

It is noted that these limits were already reached several decades ago in the central part of the Yatenga province and some parts of the Passoré province (e.g. Marchal, 1983).

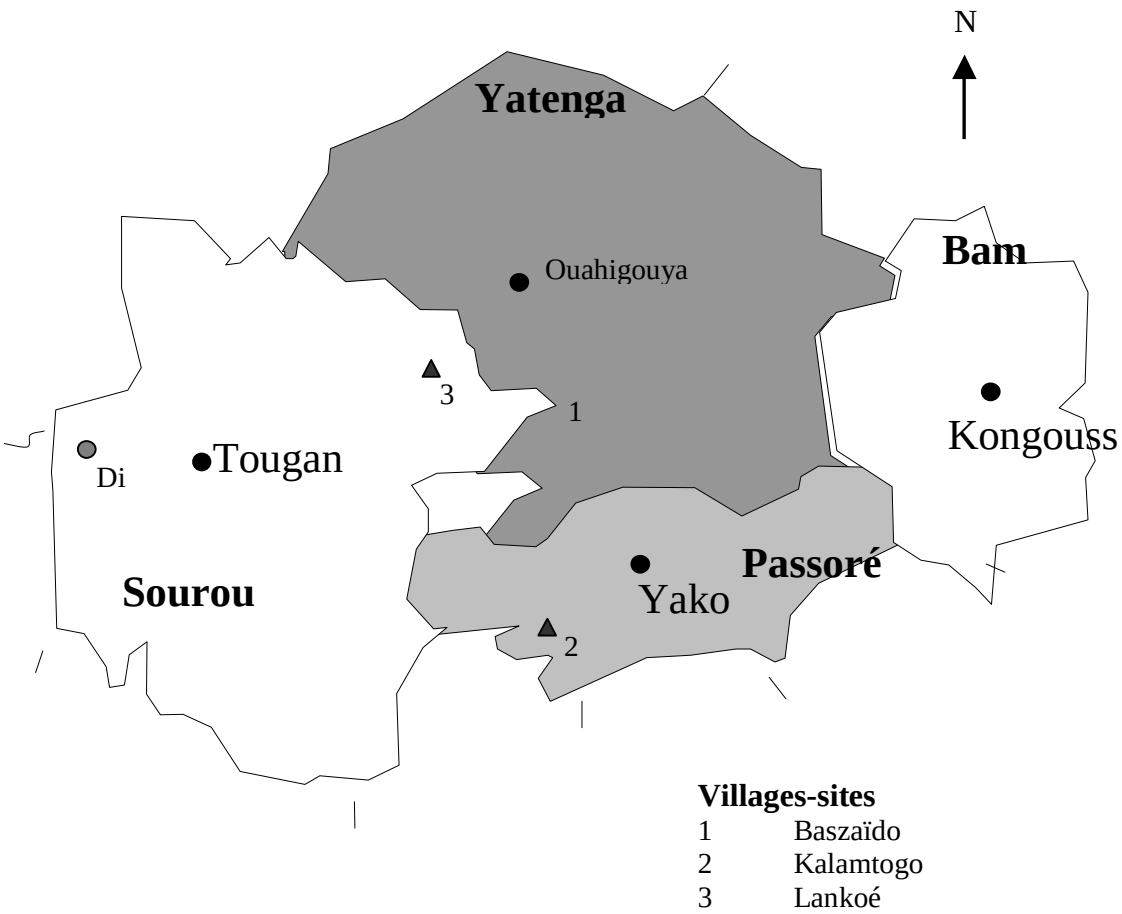
are waiting for projects to come, they have organised themselves in 'groupements' to attract money, others are looking for new opportunities, outside the village and, if possible, outside agriculture". (Young farmer in Kalamtogo, 1995)

The consequences of 'extensification' and increased pressure on natural resources are not always evident. Some farm-households seem unable to avoid the vicious circle of decreasing yields and land degradation; they become marginalized, and a growing number of their members is looking for employment outside the agricultural sector or even outside the region (seasonal or permanent migrations) in one of the larger towns of Burkina Faso or in the guinean zones, with much higher agricultural potential. Seasonal migration is not the only option any more. Permanent migration of whole families, trying to settle in the guinean zones, has become widespread in the region. However, other farm-households seem to succeed in decreasing the effects of erosion, through the construction of rock bunds and the application of soil and water conservation methods. Often, they also try to increase the organic matter production, through an increased integration of agriculture and livestock and improved methods of residue recycling (i.e. mulching). Many of them have received some kind of assistance (technical, financial) from development programs or projects, in particular for the construction of rock bunds and (small) dams[19].

The study was executed between 1992 and 1996. Primary data collection was concentrated in three villages (Baszaïdo in the Yatenga province, Kalamtogo in the Passoré province, and Lankoé in the Sourou province, see map 2), and executed in collaboration with the regional team (north-western zone) of the national farming systems research program of the Institute for Environmental and Agricultural Research in Burkina Faso (INERA). In fact, the whole study has been an integrated part of the activities carried out by this team, executing at the same time a large number of experiments together with the farmers in the above-mentioned village-sites[20].

An important reason for the construction of dams has been to promote horticultural activities in the dry season, immediately after the cereal harvest.

For more details on the work of this team see the different reports of INERA/RSP/ Zone Nord-Ouest (listed in Maatman, 2000, see in particular the synthesis report INERA/RSP/Zone Nord-Ouest, 1997), a short summary and analysis is presented in Maatman (2000, chapter 4). An overview of the surveys is given in Ouédraogo and Maatman, 1995.



Map 2: The north-western region (and study villages)

3. The methodological approach

Our analysis of farmers' strategies is a normative analysis. It tries to explore which strategies do well under various conditions, and how strategies can be improved. The normative analysis has been based on a systems approach, which mainly consisted of a systematic discussion of various concepts to be used, and of the following questions:

1)Who takes which decisions? Which decision questions are to be taken into consideration?
2)Which socio-economic and physical conditions influence the decisions? Which of these conditions are explicitly to be taken into consideration? How do these conditions influence the decisions?
3)On the basis of which criteria are the decisions taken? Which of these criteria have to be taken into account? How do these criteria influence the decisions?

The concept of a farming system has been used to structure the research and the interdisciplinary exchanges. The definition of the principal elements of a farming system (actors, physical and human resources, activity domains, 'inputs' and 'outputs') and the schematic representation of their interrelationships facilitated the comparison of the results obtained by the mathematical programming models and those obtained from fieldwork (interviews, observations, experiments), i.e. 'the reality'; it also helped to identify new orientations for a more realistic model.

An intensive study was done of a large number of secondary sources, in particular all village level studies carried out in the sahelo-sudanian and sudanian zones of Burkina Faso[21]. This study forms, together with the interviews and the observations in the field (i.e. mainly in the village-sites) the basis of this study and of all the models. Information was collected on farmers' strategies of agricultural production, of marketing, storage and consumption of agricultural products and on the influence of the factors 'land', 'labour', 'capital' and 'rainfall'. Specific attention has been given to strategies to minimise rainfall risks and in particular the risks on food shortages that result from these. One can distinguish between various strategies of risk minimisation:

1) the prevention of risks,
2) the dispersion of risks (by diversification of risky activities),
3) the control of risks through sequential decision making and
4) the 'insurance' against risks.

An example of a method of risk prevention is irrigation. The soil and water conservation methods that are practised in the north-western

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Among others the studies of ICRISAT (e.g. Matlon and Fafchamps (1988), McIntire (1981, 1983), Kristjanson (1987)), studies based on the data of ICRISAT (e.g. Fafchamps (1989, 1993), Reardon *et al.* (1988, 1992), Reardon and Peters (1991)), ICRISAT and IFPRI (Reardon and Matlon (1989)), of the program FSU/SAFGRAD (e.g. Lang, Roth and Preckel (1984), Nagy *et al.* (1986), Roth *et al.* (1986), Roth (1986), Singh (1988)), of the University of Ouagadougou (Thiombiano, Soulama, Wetta (1988)), of the University of Wisconsin (Sherman, Shapiro and Gilbert (1987)), Delgado (1977, 1978), Broekhuyse (1982, 1983, 1988), M.J. Dugué (1987), P. Dugué (1989) and Ouédraogo, I. (1991) – together with the INERA/RSP/Yatenga team –, Kohler (1971), Marchal (1983), Imbs (1987) and Prudencio (1983, 1987); the result of farming systems research published e.g. in Matlon *et al.* (1984), Ohm and Nagy (1985) and Lowenberg-DeBoer (1994) have been consulted as well. For a complete overview of the studies – including some studies focusing on social relationships – see Maatman (2000).

region can also be considered as risk prevention strategies. Methods of dispersion of risks of agricultural production refer, for instance, to the cultivation of different crops (or varieties) on different soil types applying different agricultural methods. It is useful to note that the development of livestock systems next to cropping systems is also – at least partially – a strategy to diversify risks. In general, dispersion of risk is only effective, if the effects of the different activities are not too much 'correlated'. Methods of risk control refer in this study to sequential decisions on (re)sowing and weeding during the growing season making use of information which becomes available (e.g. on rainfall, germination of plants, appearance of herbs). Livestock often functions as a method of 'insurance' against a poor harvest. If harvest fails some of the animals can be sold to buy food. In this study methods of dispersion and of control of risks have been explicitly taken into account. Insurance of risks has only been dealt with by the possible installation of a safety stock of cereals at the end of the year. Finally, the process resulted in a stochastic programming model, for 'Exploitation North-West', that describes the strategies of a hypothetical farm-household, but representative for a large number of farm-households in the north-western region. We have supposed that the 'Exploitation North-West' does not apply chemical fertilisers; moreover it does not possess the equipment nor the trained animals to practise animal traction.

4. The stochastic programming model

Introduction: some key elements of the model

The model for a representative farm-household ('Exploitation North-West') allows us to analyse crop production strategies during one growing season and consumption, storage and marketing strategies during the year following the beginning of the harvest period. This year is called target consumption year. Production decisions taken into account refer to:

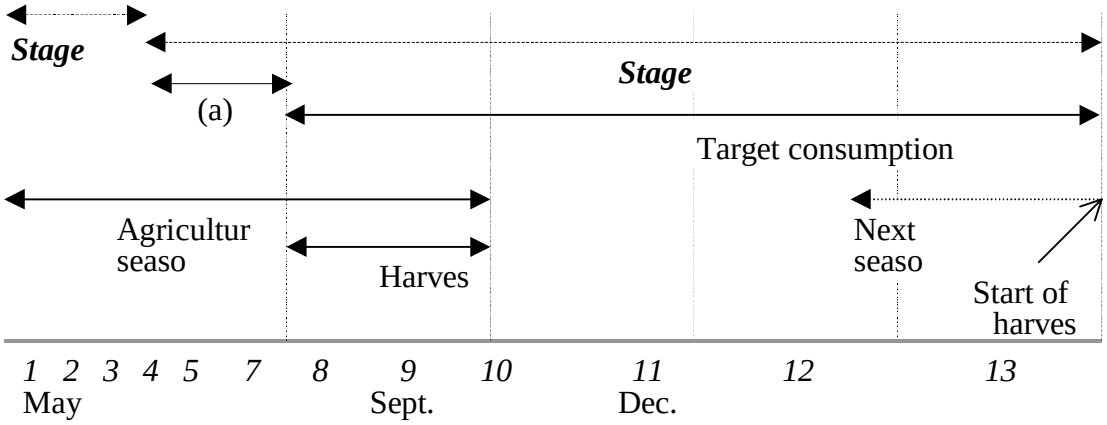
a) crop choice: the mono crops maize, red sorghum, white sorghum, millet and groundnuts, and the mixed crops red sorghum/cowpeas, white sorghum/cowpeas, and millet/cowpeas,
b) land category: dependent on the location on the 'toposequence' (low and high lands), on the distance from the compound (less than 100 metres, between 100 and 1000 metres, more than 1000 metres), and on ownership (common or individual fields),
c) method of soil preparation (ploughing, cleaning of land),

d) amount of organic manure applied (0, 800 kg, 2000 kg, 4000 kg, 8000 kg per hectare),
e) sowing dates, dependent on crop and land category (6 sowing periods)
f) levels of intensity of weeding (intensive or light)

A pivotal feature in the model developed is the concept of a plot. A plot is a piece of land with the following properties: one of the crops under a) is grown; it belongs to one of the land categories b); one of the soil preparation methods under c) is applied; one of the amounts of organic manure under d) is applied; and sowing takes place at one of the dates e). It is noticed that the level of weeding is not included in this definition; this factor will be dealt with in another manner (see below). In this way a great number of plots are distinguished. 'Representative' plots refer to combinations of crops, land categories, and agricultural methods observed in practice. Besides, a number of 'alternative' combinations is considered, to study their feasibility, usefulness and possible advantages; manual ploughing, for example, or high doses of organic manure (2000 kg/ha) on sorghum or millet fields (sole or intercropped). The area of each plot is a 'decision variable'. Their values correspond to the production decisions what, where, how much, how and when should be cultivated.

Key elements of the linear programming models describe the influence of the production factors land, labour and organic manure on the production decisions. They are called the constraints of land (per category), of labour and of organic manure. These constraints formulate the condition that required amounts of resources used can not exceed available amounts. In order to formulate the labour constraints the growing season was split up in time periods of two weeks or a month (see figure 1). In the labour constraints the required labour includes not only time of the work on the land, but also of walking from and to the fields. Organic manure is only applied on the common fields. Fallow practice is another key element of the models. It is dealt with by postulating that supplementary to each 'plot' a piece of land is left fallow. The size of this piece of land, as ratio of the size of the corresponding 'plot', depends on category of land, crop and manure level. Two scenarios of fallow practice have been analysed. The first one is based on observation of actual practice; the second one corresponds to longer fallow periods allowing (more) sustainable crop production.

Figure 1Schematic representation of the planning period.



Note: (a) = 'continuation' of the agricultural season

Decisions on consumption, storage and marketing are taken during the target consumption year, which is divided in several periods of time to allow analysis of the strategies at different times of the year. Decision variables on consumption correspond to consumption of the various products in each period, decisions on storage to amounts kept in store, decisions on marketing to quantities sold and purchased. The nutritive balances express the cereal and the non-cereal consumption in terms of nutrients (calories and proteins). In the stock equations for all agricultural products, losses and seed reserves are included as well. Financial balances also contain interest rates, and non-agricultural incomes and expenses. A few constraints, called normative constraints, are included to ensure that calculated patterns of consumption correspond to observed patterns in the north-western region. For instance, a restriction is imposed on the consumption of red sorghum, which is mainly used for beer consumption. A certain level of self-sufficiency is also required. The main objective of all strategies of the 'Exploitation North-West' together is to try to prevent, or if that is not possible, to minimise shortages of calories and proteins during the target consumption year. If these shortages can be avoided, then a stock is kept for the harvest period of the next year. If these stocks are sufficient, then the revenues are maximised. If net revenues are indeed obtained, a fraction is spent on a food security safety stock for the next year. All these objectives are dealt with in one objective function. The model is a typical multi-objective model.

Data from all secondary sources studied have been used to estimate 'average' values of parameters in the base model. For instance, yields and labour times for all plots, i.e. for all crops, categories of land, levels of applied manure, sowing dates, and levels of intensity of

weeding, have been estimated. For 'alternative plots' the values of these parameters have been estimated by extrapolating results of village level studies, and by making use of data of experimental stations. Exogenous selling and purchasing prices refer to average observed producer prices during the harvest period, and consumer prices during the lean season. The estimated values of the parameters are given and justified in Maatman (2000, appendix 4).

Sequential decision-making

In practice, farmers make their decisions sequentially, for a large part in response to the observed rainfall. In this study we have concentrated on some crucial decision-making moments, i.e. on the decisions of (re)sowing according to the arrival of rains and early rainfall at the start of the agricultural season, then on the decisions with respect to (re)sowing and weeding according to the rainfall in the period after the start of the rainy season. In principle, more stages could be distinguished, but it would make the analysis very complex. Therefore, the analysis was restricted to these two stages of the growing season. The demarcation of these two stages was not obvious. If a clear-cut distinction could be made between a first period of sowing and a late period of weeding the discussion would be easy. However, during the growing season late sowing and first weeding may coincide. Stage 1 has been chosen as the period in which most sowing decisions are taken, in stage 2 the most important weeding decisions (see also figure 1).

- ***Stage 1***: the first stage of the installation of the growing season covers the months May and June. Then most production decisions deal with soil preparation, sowing, and early weeding. In practice, these decisions are taken progressively during these two months, in particular depending on dates of the first rains. In our model three situations are distinguished: the growing season starts 'late', 'normal' or 'early'. The production decisions are different for each of these situations. So instead of one average strategy of production as in the base model, and in the second-stage model, here three different strategies are at stake: for 'late', 'normal', and 'early' starts of the growing season. If the growing season starts 'late', less time is available for land preparation (i.e. ploughing) and sowing. The number of days 'favourable' for sowing and 'effective' for ploughing are the parameters that have been used to describe the time that is available for sowing and ploughing depending on the rainfall in the first stage of the agricultural season.

- ***Stage 2***: comprises the months of July and August, called the 'continuation' of the agricultural season, and the target consumption year (starting from the first harvest of the agricultural season to the first harvest of the next season, see figure 1). The rains after the 'installation' of the agricultural season can be 'bad', 'average' or 'good'. The decisions during the 'continuation' of the agricultural season correspond to some decisions of late sowing (e.g. for maize and groundnuts) and especially of intensity of weeding. Decisions can be made of intensive or less intensive weeding, it can also be decided to abandon certain plots, planted during the first stage. 'Bad', 'average' or 'good' rainfall influences the time available for late sowing, and in particular the labour time for intensive and less intensive weeding. Yield levels – and as a result also the time required for the harvest – depend on 'bad', 'average' or 'good' rainfall in the second stage. Marketing, storage and consumption decisions are made during the target consumption year. These decisions depend on the harvest, and therefore also on rainfall.

Because there exists enough data of rainfall in the north-western region, more rainfall scenarios, both for the start as for the 'continuation' of the agricultural season could be distinguished. However, relatively few data are available on the influence of rainfall on yields and labour times, as a function of crop, soil type and agricultural methods. More importantly, the nine scenarios distinguished for rainfall in the first and second stage of the agricultural season reflect the division that is often made by farmers in order to explain results of the agricultural season. We note as well that it is not necessarily required to take into account extremely poor rainfall scenarios. Methods of risk insurance anticipate such situations.

In the model, no decision can be taken before the first observations (i.e. the realisation of the first rains) have been made. Consequently, the three-stage stochastic model can be formulated as a set of so-called two-stage recourse models, with each model corresponding to one particular outcome of the first rains (i.e. 'early', 'normal' or 'late'). The values of the first stage decision variables are determined by way of optimisation of the expectation of the value of the objective function. Each two-stage recourse model can be approximately formulated as a linear programming problem. Use is to be made of the distribution of rainfall ('bad', 'average', 'good') in the second stage. Here again, a simple approach is applied. It is assumed that there is an equal probability of having 'bad', 'average' or 'good' rainfall in stage 2. The linear programming models can be solved quickly by standard

LP software, even in small research centres in developing countries, which facilitates their application.

5. The analysis of actual strategies

According to the first results of the analyses, it appears that the food situation of the 'Exploitation North-West' is delicate indeed. Annual consumption targets are attained only in 5 of the 9 rainfall scenarios. It produces between 55% (very poor rainfall season) and 140% (very good rainfall season) of its nutritional requirements; based on the supposition that 20% of the energy requirements are covered by other products (meat, leaves etc.). In 8 of the 9 scenarios, the 'Exploitation North-West' buys more cereals for consumption (during the 'lean' season, just before the harvest) than it sells. The sale of cereals, but also of groundnuts and cowpeas, is necessary to satisfy certain (non-food) expenditures of the farm-household. The non-agricultural revenues are in 4 of the 9 rainfall scenarios not sufficient to buy the cereals that are – in principle – required for consumption. In most cases, the farm-household adapts to this situation, simply by rationing strategies. This concurs to what we have found in the consumption surveys that we held in the village-sites. However, in very bad rainfall years, the food-deficits of the 'Exploitation North-West' become unbearable. Survival then depends for a large part on the capacity of 'risk-assurance' strategies. It is noted that the levels of agricultural production and of consumption correspond well to the reality of the farm-households in the region. The vulnerability of farming systems is caused for a large part by the climatic conditions that are not very favourable for agricultural production, the scarcity of fertile soils and a lack of alternative economic opportunities. Some major results that follow from the analyses – introducing some nuances to the alleged precarious situation of the 'Exploitation North-West' – bear on the following points:

1) The ***heterogeneity*** of agricultural strategies, i.e. the cultivation of different crops, sometimes 'pure', sometimes intercropped, on different soil types, and using a great diversity of growing methods (different sowing periods, with different quantities of organic manure, intensive and less intensive weeding). The great diversity in agricultural activities, in response to a complex range of objectives and constraints, is a key element of the farmers' strategies in the north-western region. The results for instance show the particular role of mixed crops. They are especially grown in an

'early' or 'normal' growing season. In a 'late' season sole cropping is preferred. Another example is the growing of maize. Maize is a lean-season crop, since it is harvested during the first weeks of the harvest period, just before the harvest of the (large) millet fields. Since reserve stocks of the preceding year are often empty long before this period, the harvest of maize helps in decreasing consumption expenses and in minimising, or even preventing, food shortages.

Differences also exist between the strategies of the 'Exploitation North-West' on the common and those on the individual fields, where the women of the farm-household make the decisions. Millet and groundnuts are produced on these individual fields, cultivation of sorghum and maize is not efficient because of the lack of manure. Relatively more groundnuts are cultivated on the individual fields than on the common fields. The analyses show that the labour requirements for groundnuts fit relatively well to the availability of labour for the individual fields.

2) The ***flexibility*** of the production strategies. They differ greatly according to rainfall patterns. In the distinguished scenarios of the 'installation' of the growing season ('late', 'normal' and 'early') and of the rainfall later in the season ('bad', 'average', 'good') this flexibility can best be illustrated for two extreme situations:

- a 'late' start of the growing season and bad rainfall later in the season: time for sowing is limited. Poor rainfall conditions limit the growth of weeds, all weeding can be done intensively. Yields and production are low.
- an 'early' start of the growing season and good rainfall later in the season: much more labour time for sowing is available. Now, labour time for weeding is very restrictive. In fact, the 'Exploitation North-West' is obliged to abandon part of its fields and another part is weeded less intensively. Yields and production are relatively high.

The results of the model of the 'Exploitation North-West' show again that farmers choose strategies of land preparation, sowing and early weeding which anticipate poor rainfall conditions later in the growing season. This result is quite understandable. Farmers intend to orient towards flexible cropping systems, for instance to the cultivation of crops like millet, which can endure low levels of crop management. Due to its resistance against weeds, weeding of

millet can be done less intensively without reducing the yields too much. Risk minimisation strategies – and in particular the strategies to control risks – favour the 'extensification' of agricultural production systems. Besides, the 'Exploitation North-West' is not executing – for the same reason – any ploughing on the fields, except for the fields where maize and groundnuts are grown; even when the rains in the first stage of the agricultural season start very early, only some small cereal plots are ploughed. It is therefore not surprising that the adoption of the models of intensive agriculture, proposed by a large part of the development structures in the north-western region, appears to be very limited.

3) The ***resilience*** of the farming system. This points to the substantial capacity the 'Exploitation North-West' to adapt themselves to difficult conditions, and in particular to increasingly severe constraints of land availability. The adaptive capacity of farm-households in the north-western region is certainly much higher than certain authors and development agents want to recognise. The sensitivity analyses, for instance, show that even with an important decrease of the available land (-25%), the 'Exploitation North-West' still seems to be able to provide their members with enough food, at least for most of the years; of course, using – as usual – the revenues obtained outside agriculture, and by adapting its strategies to the decreasing availability of land. However, this apparent resilience does not provide a guarantee for the long term. This is even truer when we consider that actual levels of crop production can only be realised at the expense of soil fertility. We recall that in our study the handling of fallow practices was based on practices observed in various village studies. In many people's opinion, the actual fallow practices are, however, insufficient to allow sustainable cultivation on long term. The fallow periods are too short to restore soil fertility. In a sensitivity analysis we have computed the consequences of more sustainable fallow practices (i.e. based on a 20 to 30% decrease in land-use intensity for each plot). The nutritional value of agricultural production decreases by 10%. Apparently, the 'Exploitation North-West' can not permit itself such a reduction of agricultural production; and is more or less 'forced' – like the majority of farm-households in the region – to overexploit the land.

4) The ***independence*** of the strategies of 'Exploitation North-West' against price variations of agricultural products on the market. Sensitivity analysis shows that even considerable price variations

for agricultural products, while maintaining the same ratio between selling and purchasing prices, do not seem to have a big influence on the agricultural production strategies and the commercialisation of agricultural products. This result confirms that the farmers react to the prices only marginally. Nevertheless, a drop in the price of cereals seems to be interesting for the 'Exploitation North-West'. These results are based on the fact that the household is not able to assure the consumption needs by its own crop production, neither directly by auto-production, nor directly by selling a part of the crop production. The 'Exploitation North-West' is a net buyer of cereals. The households are dependent on the markets for purchasing cereals rather than for selling their surplus.

In a normative analysis one does not only expect results that are conform actual practices. The analysis has clearly shown that nutritive demands can be better satisfied, if part of the cereal consumption is replaced for instance by the consumption of groundnuts. So, diversification of produce can improve levels of food security. There are also other reasons why diversification of consumption is desirable, for instance to prevent deficiencies of vitamins. However, it will not be easy to change the modes of consumption of the rural populations in the north-western region, that are based almost exclusively on cereals (millet and sorghum).

6. The analysis of short and medium term perspectives: farmers' initiatives

The agricultural production system of the 'Exploitation North-West' is characterised by strategies of diversification and (risk) control (see above), resulting from risk (of bad harvests) minimisation objectives and from optimising criteria with respect to the resources of production (in particular of labour). The farmers seem to make maximal use of the available resources. It follows from all our analyses that for the 'Exploitation North-West' with its scarce resources of land, labour, and organic manure, and with no capital for investment in agriculture the margins for improving the food situation by intensifying production are very little. Other measures have to be taken to improve the situation.

Methods of anti-erosion, and soil and water conservation methods
Different measures are undertaken by the farmers in the north-western region to slow down or to stop erosion, and to optimise the supply of water and nutrients to the plants. Particular attention has been given to

the rock-bunds, anti-erosion devices that have generated a lot of excitement among the farmers in Burkina Faso, and in particular in the provinces of Yatenga, Bam and Passoré (see for instance Dialla, 1992, Sawadogo, 1996, Kaboré *et al.*, 1994a,b). Rock bunds are lines of stones that are placed along the contour lines, of variable length and wings folded upstream. The stones do not stop the water, but slow down the water streaming downwards, improving infiltration and the accumulation of fertile deposits, while evacuating excess water. These measures should permit on the middle and/or on the long term to improve the productivity of the land and assure the conservation of natural resources. Another interesting anti-erosion method is <zaï>. <Zaï> is applicable at the farm-household level. It is an intensive method of manure management and water conservation. It has already been practised for a long time in the Yatenga province in the north of Burkina Faso, to recover the poorest parts of the land. Nowadays this method is used in all regions in Burkina Faso where degradation is important. It consists of digging holes, putting in organic manure, and then sowing. The holes are covered with soils from the lower areas; the micro-environment created makes the plant better resistant to droughts and the yields will grow substantially. <Zaï> permits recovery of degraded soils.

Our analysis of the <zaï> method and the rock bunds demonstrated the important potential of these methods (Maatman, 2000: chapter 11). They decrease the rate of erosion on the fields and contribute to improved conservation of water and soils. Moreover, the <zaï> method increases the efficiency of the organic manure, of which the available quantities are very limited. With the rock bunds (only in the 1st and 2nd rings!) and applying the <zaï> method on a (small) part of the area, the 'Exploitation North-West' was able to increase the nutritional value of the agricultural production on average with 5%, and with 10 to 12% in years with a bad rainfall. The extension of rock bunds in the 3rd ring would certainly be beneficial. However, such an extension comes up against problems of labour and transportation means (to collect the stones). Besides, the effect of rock bunds is more important when it is combined with intensive agricultural production on the fields that profit from the increased conservation of water and land through applications of organic manure, and eventually of chemical fertilisers; however the availability of these inputs is limited. The extension of the <zaï> practice is also difficult due to the limited availability of organic manure and by labour constraints. Finally, the efficiency of the <zaï> method is highest when the soils are very poor and the availability of land limited.

Strategies of integration of agriculture and livestock

At present, integration of crop cultivation and keeping of livestock is in its infancy. One can observe an increase of farmers' interest in methods of stalling, of collection of manure, of making compost, of storing crop residuals etc. (see e.g. Sienou, 1996). The adoption of such methods goes slowly differing from region to region, even from household to household. The strengthening of the integration requires many efforts by farmers and extension officers, but also much agricultural research. A large number of constraints and problems related to integration have not yet been solved: feeding of the animals is often difficult, e.g. because of decreasing quality of the pasture lands; methods to improve livestock management (vaccination, stalling) are often too expensive or the farmers are not familiar with them; water for livestock may be limited; improved livestock management may compete for labour etc.

The perspectives of the integration of agriculture and livestock, based on a simple reinforcement of actual practices to exchange sub-products of livestock (manure) and agriculture (residues), are meagre (see for more details Maatman, 2000: chapter 12). This seems particularly true for strategies that aim to increase the number of animals (to obtain more manure). These strategies amplify the difficulties of feeding in the dry season and do not constitute a solution for most of the farm-households (except in some sub-zones where pasture lands are still relatively abundant). Given the actual conditions in most of the sub-zones of the region, it seems more efficient to try to improve the rate of use of the residues for forage and – if possible – the collection of forage crops (weeds) in the bush. It could also be tried to increase the quantity of manure available, by intensifying the collection of excrements of the animals during the nocturne parking. The improvement of the quality of organic manure through composting could also be an option, but needs considerable labour, water and – also – crop residues.

7. Long term perspectives: integrated and more intensive production systems

In sum, we may conclude that the actual situation of the ‘Exploitation North-West’ is precarious. The analyses even seem to suggest that the ‘Exploitation North-West’ is caught in survival strategies, and moving, slowly but surely, away from the subsistence economy of the past. At the same time, it is recognised that the ‘Exploitation North-West’

possesses a remarkable capacity to adapt itself, as well as is possible, to worsening conditions for agricultural production, and in particular to demographic growth (i.e. reducing the availability of land). However, this capacity – based on 'traditional' principles of adaptation – begins to weaken. In the longer run other initiatives will be necessary to face population growth and continuing degradation of natural resources. We can make a distinction between two situations:

- The pressure on agricultural areas is not increasing, due to migration and the growth of employment opportunities outside the agricultural sector. In this case, agriculture based on low 'external' input use and 'rational' use of local resources seems to be able to maintain itself.
- The pressure augments and soils progressively degrade.

The last situation is the most probable for most sub-zones in the north-western region. Possibilities for intensification of agricultural production will develop, if population growth is coupled with increased market exchanges and some general economic development. Intensification will be based on the use of 'external' inputs, and in particular on chemical fertilisers. To minimise financial risks, it is important to reduce transaction costs, and to fine-tune existing technologies. The combination of chemical fertilisation with soil and water conservation methods, and with organic fertilisation (mulching, applications of organic manure) seems to be the most suitable strategy. Animal traction also deserves special attention. The study concludes that there are no easy solutions. In the short term it seems very inefficient to undertake ambitious and hasty projects to promote intensification processes in the north-western region. Such projects are bound to fail, except maybe in some small regions (i.e. the villages close to the major road connecting Ouahigouya and Ouagadougou, the irrigated area in the Sourou valley). It will be – for the time being – more useful to support local initiatives of land-management, both at the village and the farm-level, and methods of low-external-input agriculture (recycling of crop residues, collection of manure, application of soil and water conservation methods, use of chemical fertilisers in combination with applications of organic matter on small 'intensive' plots). Such an 'adaptive' approach is without doubt more interesting for farmers in the region; at the same time it could stimulate farmers to experiment with other (more intensive) methods, that aim to raise the challenge of the days after tomorrow.

In view of these ideas and observations, an 'enabling' approach (De Janvry and Sadoulet, 1993) seems to be most indicated for (regional) food security policies. Despite the so-called disengagement of the state and the reduction of its expenditures, it remains essential to extend public investments invest in physical infrastructure, in education and health. Such an approach includes programs that aim to improve market infrastructures and rural institutions. Progressively, we will come to know if the north-western region is developing into a region with intensification potential. However, if food security policies play an important role, their effects must not be over-estimated. The perspectives of the north-western region depend foremost on the creativity and the perseverance of the rural populations themselves[22].

8. Final observation

The models that have been used in this study are instruments of analysis. They aim to determine what farmers 'should' do, based on a specific formulation of the farming system, including its physical and socio-economic environments. In this study, the definition of decision questions, physical and socio-economic conditions, decision-making criteria and their interrelationships have received ample attention. Together, these elements constitute the farming system. The systems approach provided the framework for this study. The models were developed in several phases. First, a very simple model was developed, based on a restricted number of decision questions and on some simple hypotheses with respect to the physical and socio-economic conditions and the decision-making criteria. The discussion of the results of this model, including those of certain sensitivity analyses, were used to identify the most important elements that should be integrated in the modelling process, leading to more realistic results. The step-wise approach led to major improvements of the model[23]. The inclusion of the sequential decision-making process, and the distinction between

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This should be a major lesson also for the many development projects in the region. Despite the 'participatory' rhetoric, most projects are still very much governed by 'external' agenda's. They often fail to achieve the most important goal: to strengthen the innovative capacities of the target-population. Without real involvement (and – adequate – control!) of the rural populations, most projects will continue providing (temporary) relieve (if at all), which ultimately only reinforces the feelings of non-control.

The stepwise approach and the models – from simple to more complex – that have been developed are presented (for the Central Plateau region in Burkina Faso) in Maatman and Schweigman (1995) and Maatman *et al.* (1996).

light and intensive weeding, was such a step. It proved to be a crucial step, as solutions came much closer to what we observed in reality. In particular it explained the close relationship between on the one hand the minimisation of risks and on the other hand flexible cropping systems and farmer's extensive land-use practices. Finally, the organisation of a continuous and systematic discussion on a given set of problems, with the aim to formulate a mathematical programming model, was a useful experience. It permitted to make an in-depth analysis of the problems of farmers in the north-western region, and to share knowledge and to exchange ideas and different points of view with a large number of actors.

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The Importance of Public Investments and Institutions for the Functioning of Food Markets in Developing Countries

Peter Hazell and Shenggen Fan

1. Introduction

Public investment in rural areas has stagnated in recent years in many developing countries and has fallen as a share of total government expenditure and of agricultural GDP (Fan and Rao, Forthcoming). Government spending in rural areas has even declined in many poor African countries. This stagnation has been driven in part by the need to cut total public expenditure as part of structural adjustment programs, but also by the low priority attached to agriculture since the mid-1980s by many governments and donor agencies.

Are national policy makers and donor agencies correct in neglecting rural investment? This paper presents recent evidence from work at IFPRI showing that public investments in rural areas have been very instrumental in generating agricultural productivity growth, and that they continue to give very reasonable returns in terms of both economic growth and poverty reduction, even in countries that have already invested heavily in their rural areas. Guidance is also provided on the kinds of investments by type and region that give the best returns.

These results have special importance for most African countries given their already low levels of rural infrastructure and human capital development and stagnant agricultural sectors. Map 1 shows road density in Uganda, one of better countries, overlaid with population data. Although there is a pretty dense road network in the major populated areas, especially near Lake Victoria, there are vast areas of the country where many rural people do not have access to roads, even low quality ones. Although we do not yet have accurate data on the proportion of Africa's farmers who are far removed from roads and transport systems, it seems likely that the vast majority is disadvantaged in this way.

Spencer (1994) compared the density of Africa's road network in early 1990s with that in India in 1950s prior to the green revolution (Table 1). India had nearly six times the density on average. If one takes the Indian density as broadly indicative of what is needed for rapid agricultural growth, then it is clear that Africa will need massive investments in rural infrastructure before it can launch a successful agricultural revolution.

Table 1: Rural Road Network in the Humid and Sub-Humid Tropical (HST) Countries of Africa

Country	Density in Africa in early 1990s (Km/1000 sq. km)	Required Density to match India in 1950 (Km/1000 sq. km)
Benin	36	291
Cameroon	38	168
Congo	1	47
Cote d'Ivoire	94	258
Ghana	17	429
Madagascar	67	137
Mozambique	17	135
Nigeria	97	718
Sierra Leone	80	391
Tanzania	66	181
Zaire	36	110
All HST	63	388

Source: Spencer, 1994

2. Estimating Returns to Public Investments in Rural Areas

Recent work at IFPRI has led to econometric estimates of the marginal impacts on agricultural production and poverty of public investments in different types of rural infrastructure. Since there are different versions of the model in terms of the way key variables are defined and measured, and the level of regional disaggregation achieved, we present only a stylized version of the model here. Additional details about the various model specifications can be found in the papers referenced below.

There are five key equations in the model:

1)AGP = f(FARMINP, TECH, IRRIG, INFRA, ATT)
2)NFE = F(AGP, IFRA)
3)WAGE = f(AGP, INFRA)
4)ATT = f(AGP, WP, I)
5) POV = f(AGP, NFE, WAGE, ATT)

Equation (1) is the agricultural production function, where production (AGP) is either agricultural output or total factor (or labor) productivity. Explanatory variables include a set of traditional farm inputs (FARMINP) such as labor, land, fertilizer, machinery, and draft

animals; technology (TECH)*;* irrigation (IRRIG); a set of rural infrastructure variables (INFRA) such as roads, rural electrification, education and telecommunications; and the agricultural terms of trade (ATT), typically lagged by one period. Annual rainfall is also often included and a time trend variable to capture any time-related changes not captured elsewhere. All explanatory variables are expected to have a positive impact on agricultural production.

Equation (2) is a nonfarm employment equation. The dependent variable is either the number or percentage of rural laborers engaged in rural nonfarm activities. Independent variables are growth in agricultural production or productivity, and rural infrastructure (including education). Equation (3) is a rural wage equation with growth in agricultural production or productivity and rural infrastructure as independent variables. Equation (4) is a terms-of-trade equation that models how growth in agricultural production or productivity would affect agricultural or food prices. World food prices (WP) and national per capita income (I) are also included as independent variables.

Equation (5) is the rural poverty equation. Rural poverty (POV), measured as the percentage of the rural population falling below the official poverty lines, is modeled as a function of agricultural production (AGP), rural nonfarm employment (RNE), the rural wage (WAGE), and the agricultural terms of trade (ATT). Increases in agricultural output, rural nonfarm employment, or wages should help the poor to increase their incomes, and hence reduce poverty, while increases in the price of food can be expected to increase poverty in the short run. However, in the long run, improvements in the terms of trade should stimulate greater investment in agricultural production (as in equation 1) and lead to higher levels of productivity that can benefit the poor.

The technology and infrastructure variables are measured in physical or monetary form depending on the kinds of data available. When modeling at the national or state level , time series data on public expenditures are used to estimate additional equations relating the value of stocks of the technology and infrastructure variables to past patterns of government expenditure. Additional equations with distributed lag structures are then estimated as part of the model structure. When using data at more disaggregated regional levels (e.g. districts or counties), the model is estimated only with physical measures of technology and infrastructure on the right hand side.

Typical physical measures are the share of cropped area planted to high yielding varieties (for TECH) or the crop share that is irrigated (IRRIG), the density of rural roads in terms of km per km^2 of geographic area, and the literacy rate of the rural population.
Due to endogeneity problems, several variables, especially the rural wage, technology, irrigation, and terms of trade variables, are also specified with their own equations as part of the system. Other potential endogeneities are handled by using appropriate systems estimation techniques.

Once the model has been estimated, the marginal impact of additional investments in an infrastructure or technology on agricultural productivity or poverty can be measured by totally differentiating the full equations system with respect to each investment variable of interest. Depending on the type of technology and infrastructure data used, marginal impacts are measured per unit of physical stock or per dollar added to the existing stock.
When dollar values are used, the growth returns are measured as the discounted value of future costs and benefits, using the estimated lagged structures to calculate the benefit and cost streams over time. Poverty impacts are calculated for a chosen year using the poverty elasticity of growth and the discounted costs of each investment, again based on the estimated lag structures. All marginal impacts are calculated for the last year of the time series sample used.

3. National Results

India

In a study of public investment in rural India conducted by Fan, Hazell and Thorat (2000), state level data were pooled for 1970-93 to estimate the impacts of different investments on agricultural total factor productivity growth (TFP), rural wages, nonfarm employment, and poverty reduction for all India (Table 2). The marginal impacts were calculated for 1993.

Additional investment in agricultural R&D has the largest impact by far on agricultural growth and the second largest impact on poverty reduction. Additional investment in rural roads has the largest impact on poverty and the second largest impact on growth. These two investments dominate all others in terms of the size of their impacts, and can be considered the best win-win strategies for achieving growth and poverty alleviation. Education ranks a distant third for both growth

and poverty alleviation. Investments in soil and water conservation and rural development have the fourth and fifth largest impacts on poverty reduction, but only modest impacts on productivity growth. They are primarily used as relief employment schemes, but there is clearly a tradeoff between the use of government funds for short-term relief verses growth and long-term poverty alleviation. Additional investments in irrigation rank poorly for growth and poverty reduction. This is partly because most of the good irrigation projects have already been done, but also because public irrigation schemes are managed very inefficiently. Investments in rural health have only modest impacts on growth and poverty alleviation.

Table 2: Poverty and Productivity Effects of Government Investments in Rural India.

Expenditure Variable	*Productivity Returns in Agriculture in Rupees per Rupee Invested*	*Number of People Lifted Out of Poverty per Million Rupees Invested*
R&D	13.45	84.5
Irrigation	1.36	9.7
Roads	5.31	123.8
Education	1.39	41.0
Power	0.26	3.8
Soil & water	0.96	22.6
Rural development	1.09	17.8
Health	0.84	25.5

Source: Fan, Hazell and Thorat, 2000, but with new and unpublished calculations by Fan of the benefit/cost ratios.

China

Fan, Zhang and Zhang (2000) have estimated a similar model for China using province level data for 1970-97 (last column of Table 3). The marginal impacts were calculated for 1997.

As in India, additional investment in agricultural R&D gives the highest growth at the national level and the second largest impact on poverty reduction. But unlike India, education investments rather than roads have the largest impact on poverty and the second largest impact on agricultural growth. These two investments dominate all others and can be considered win-win for growth and poverty alleviation. Rural roads rank third for growth and poverty alleviation, followed by

investments in power and communications. Irrigation investments again rank poorly for both growth and poverty alleviation, and probably for the same reasons as in India. Investments in poverty loans, a targeted assistance program for the poor, have no measurable impact on agricultural GDP growth, and the smallest impact on poverty reduction of all the investments considered. Again there is a high tradeoff between short-term relief and growth and long-term poverty reduction.

Table 3: Marginal Returns to Infrastructure and Technology Investments in Rural China

	Coastal	Central	Western	National
Returns to Agricultural GDP in Yuan per Yuan Invested)				
R&D	8.60	10.02	12.69	9.59
Irrigation	2.39	1.75	1.56	1.88
Roads	1.67	3.84	1.92	2.12
Education	3.53	3.66	3.28	3.71
Electricity	0.55	0.63	0.40	0.54
Rural Telephone	1.58	2.64	1.99	1.91
Number of People Lifted Out of Poverty per 10,000 Yuan Invested				
R&D	1.99	4.40	33.12	6.79
Irrigation	0.55	0.77	4.06	1.33
Roads	0.83	3.61	10.73	3.22
Education	2.73	5.38	28.66	8.80
Electricity	0.76	1.65	6.17	2.27
Rural Telephone	0.60	1.90	8.51	2.21
Poverty loan	0.88	0.75	1.49	1.13

Sources: Fan, Zhang and Zhang, 2002

Discussion

Agricultural R&D, roads and education are the three best investments in both India and China for achieving agricultural growth and poverty

reduction. Agricultural R&D has the biggest growth impact in both countries, and the second largest impact on poverty reduction.

Many investments in rural areas still offer good productivity returns despite the large amounts of investments that have already been made in these two countries. For India, the benefit/cost ratios in Table 2 exceed 1 for most investments, and are very high for R&D and roads. These investments can be justified even at high discount rates for public funds. The China results in Table 3 also show that most types of investments have favorable benefit/cost ratios (value of agricultural GDP generated per Yuan of investment), and are especially attractive for R&D, education and roads.

3. Regional Results

An important issue for many developing countries is the allocation of public investments across different types of regions. Past public investments have typically been biased towards irrigated and high-potential rainfed areas. Conventional wisdom suggests that the productivity returns to investment are highest in these areas, and that growth in these areas also has substantial trickle down benefits for the poor, including those residing in less-favored areas. For example, the poor in less-favored areas will benefit from the cheaper food produced in high potential areas, from increased market opportunities for growth, and from new opportunities for workers to migrate to more productive jobs in the high-potential areas and in towns. Fewer people will try to live in less-favored areas, and this will help reduce environmental degradation and increase per capita earnings. Migrants may also send remittances back to less-favored areas, further increasing per capita incomes there, especially for the poor.

Many of the expected benefits arising from rapid agricultural growth in high-potential areas have been confirmed through empirical research. Nevertheless, the rationale for neglecting less-favored areas is being increasingly challenged by: a) the failure of past patterns of agricultural growth to resolve growing poverty, food insecurity and environmental problems in many less-favored areas; b) increasing evidence of stagnating levels of productivity growth and worsening environmental problems in many high-potential areas; and c) emerging evidence that the right kinds of investments can increase agricultural productivity to much higher levels than previously thought in many less-favored areas. It now seems plausible that additional public investment in many less-favored areas may have the potential to generate competitive if not

greater agricultural growth than comparable investments in many high-potential areas, and that these investments could have a greater impact on poverty. If so, then additional investments in less-favored areas may actually give higher aggregate social returns to a nation than additional investments in high-potential areas. In fact, they might even offer win-win-win possibilities. We have tested this hypothesis for China and India.

China

The results for China in Table 2 are disaggregated by three regions: the coastal, central, and western regions. The coastal region is the most fertile with good rainfall and can be classified as a high-potential region. The western region is the least developed and has poor natural resources and social infrastructure; it is a low-potential area. The central region is intermediate between the other two, and from an agricultural perspective can be considered a mid-potential area. More than 60 percent of the rural poor lived in the western region in 1996 and most of the rest lived in the central region.

Apart from irrigation, all investments have their biggest impact on poverty in the low-potential western region and their second biggest impact in the mid-potential central region. The high-potential coastal region ranks second or third for all investments. Most investments also have their highest production returns in either the central or western region, showing that investments in these regions are now win-win strategies. However, the production returns are mostly larger in the central rather than the western region, suggesting that some trade off exists between growth and equity goals in allocating investments between mid-potential and low-potential areas.

Irrigation investments yield their highest return in the coastal region, where they also have favorable poverty impacts. In contrast, agricultural R&D has its biggest production and poverty impacts in the western region.

India

Fan and Hazell (2000) undertook an analysis for India using district level data, where districts were classified into three categories: irrigated, high-potential rainfed and low-potential rainfed. Districts were defined as irrigated if more than 25 percent of the cropped area was irrigated, otherwise they were classified as rainfed. Rainfed districts were further subdivided into high- and low-potential areas according to their agroecological characteristics. Using district-level

data for 1970-95, an econometric model was estimated to measure the impact of different types of public investments on agricultural production and rural poverty. The model was then used to calculate the impact on growth and poverty of another unit of each type of investment by land type. The results are shown in Table 4.

Table 4: Marginal Returns to Infrastructure and Technology Investments in Rural India

Investment Variable		Irrigated Areas	High-Potential Rainfed Areas	Low-Potential Rainfed Areas
Production returns (1990 prices)				
HYV	Rs/Ha	63	243	688
Roads	Rs/Km	100,598	6,451	136,173
Canal Irrigation	Rs/Ha	938	3,310	1,434
Private Irrigation	Rs/Ha	1,000	(2,213)	4,559
Electrification	Rs/Ha	(546)	96	1,274
Education	Rs/worker	(360)	571	102
Poverty reduction				
HYV	Persons/Ha	0.00	0.02	0.05
Roads	Persons/Km	1.57	3.50	9.51
Canal irrigation	Persons/Ha	0.01	0.23	0.09
Private irrigation	Persons/Ha	0.01	(0.15)	0.30
Electrification	Persons/Ha	0.01	0.07	0.10
Education	Persons/worker	0.01	0.23	0.01

Note: The numbers in parentheses are negative. In most cases these negative coefficients were not statistically significant.
Sources: Fan and Hazell (2000).

For every investment, the highest marginal impact on agricultural production and poverty alleviation occurs in one of the two rainfed lands, while irrigated areas rank second or last. Moreover, many types

of investments in low-potential rainfed lands give some of the highest production returns, and all except markets and education have some of the most favorable impacts on poverty.

To delve further into these spatial relationships, Fan, Hazell and Haque (2000) undertook a similar analysis at an even more spatially disaggregated level. They classified rural districts into predominantly irrigated or rainfed agriculture, and then subdivided the rainfed areas into 13 agroecological zones, numbered in order of their land productivity (1 being the highest). Data for 1970-94 were then used to estimate the impacts of different types of investments on agricultural growth and poverty reduction in each land type (Fan, Hazell and Haque 2000). For every investment, the highest marginal impact on agricultural production and poverty alleviation occurs in one of the rainfed lands, while irrigated areas often rank quite low (Tables 5 and 6).

Table 5: Marginal Returns to Investment in Infrastructure and Technology Variables by Agro-Climatic Zone, Rural India[a]

	Normal Rainfall (mm/yr)	High Yielding Varieties	Roads	Canal Irrigation	Electricity	Education
Irrigated areas	858	4.64	26.80	2.76	0.86	0.22
Rainfed zones[b]:						
1	1690	0.00	38.38	4.90	1.18	0.10
2	1391	26.14	8.29	6.27	10.02	1.54
3	986	7.50	102.83	3.17	5.15	0.09
4	902	0.00	29.94	3.63	0.80	2.50
5	960	0.86	37.88	2.19	1.28	0.86
6	918	12.87	135.85	3.51	1.09	1.07
7	965	29.80	100.47	6.96	4.44	0.94
8	924	0.41	137.28	7.81	4.28	2.41
9	508	5.30	82.53	1.95	2.92	10.55
10	649	9.21	9.14	0.14	6.90	6.76
11	443	0.02	2.57	2.53	0.16	11.93
12	719	10.67	50.88	2.71	5.78	1.10
13	335	0.00	113.29	0.00	31.42	12.37

a. Rs output per Rs investment
b. Zones ranked by land productivity (1 = highest)
Source: Fan, Hazell and Haque (2000)

Moreover, several types of investments also give favorable returns in the poorer rainfed lands and have some of the most favorable impacts

on poverty. Rural roads and education scored particularly well on both growth and poverty outcomes, as did irrigation in areas where untapped water resources are available. The returns to agricultural research in the poorest areas were more mixed, possibly because the study was only able to capture the returns to crop improvement research and not the returns to natural resource management research.

Table 6: Reduction in number of poor for an additional one million rupees (1994 prices) invested in technology and infrastructure by agroclimatic zone, rural India

	High Yielding Varieties	Roads	Canal Irrigation	Electricity	Education
Irrigated areas	0.76	8.02	0.46	1.56	0.48
Rainfed zones[b]:					
1	0.00	25.69	1.00	12.47	1.09
2	32.56	55.07	0.55	26.37	3.83
3	0.97	35.84	0.05	11.20	2.16
4	0.00	35.98	0.00	7.15	7.01
5	0.72	39.75	1.85	4.10	1.24
6	13.43	165.35	0.44	5.65	3.01
7	5.44	18.34	8.82	8.97	3.36
8	0.17	0.00	0.98	3.33	3.02
9	1.21	25.29	1.85	2.37	3.73
10	3.39	1.02	0.00	11.82	5.66
11	0.00	2.60	0.48	0.03	2.54
12	0.00	1.75	1.88	26.21	8.93
13	0.00	n 6.06	12.43	1.68	0.66

[a] *Persons per million rupees in 1994 prices.*
[b] *Rainfed zones are ranked by land productivity (1 = highest, 13 = lowest).*
Source: Fan, Hazell and Haque (2000).

Discussion

These results from India and China provide strong support for the hypothesis that investments in less-favored areas are becoming win-win opportunities, and that more investment should now be channeled to less-favored areas in both countries. However, the results should not be interpreted to mean that public investment should now be reduced in irrigated and high-potential lands. These areas are the major sources of food for rapidly growing urban populations and they still offer favorable returns to many investments. But the results do suggest that there are attractive opportunities for reducing poverty through

additional investments in less-favored areas, and that rather than sacrificing growth, many of these investments actually offer win-win opportunities for achieving more production growth and greater poverty reduction.

Similar studies have yet to be done for other regions, and it would be dangerous to extrapolate these results beyond Asia, since many poorer countries, especially in Africa, have not yet invested sufficiently in their high-potential areas to have reached the point of diminishing production returns. Similar studies are needed of different types of developing countries. We now have such work underway at IFPRI.

4. Supplying Rural Infrastructure and Rural Services

The previous section has highlighted the importance of investments in rural infrastructure, technology and other key public services for achieving growth and reducing poverty in rural areas. Many of these investments also offer high returns, even in countries like India and China that have already invested heavily in their rural areas. Unfortunately, public investment in rural areas has fallen in many developing countries in the past decade or so due to the fiscal pressures imposed on governments through structural adjustment programs and a precipitous decline in donor support for such fundamentals (Fan and Rao, forthcoming). There has also been an over zealous downsizing of the public institutions that provide essential public goods and services like R&D, infrastructure, education and health, and this will also need to be reversed. These institutions still have key roles to play and need to be revamped and strengthened to fulfill their functions in cost effective and demand responsive ways. The challenge for many developing countries is to find effective ways to pay for additional public investments, and to develop suitable institutional arrangements for their delivery.

Better targeting of public investments in rural areas is one way to improve the effectiveness of available public resources. This paper has shown that the productivity and poverty impacts of different types of investments vary widely, and policy makers seeking to maximize growth and /or poverty alleviation goals should choose investment portfolios that maximize these goals. Investments in agricultural R&D, roads and education score well on both counts, as do greater investments in many less-favored areas. Similar studies to the China

and India work are needed for other countries to provide similar guidance for their investment portfolios.

Reducing the unit cost of key infrastructure and public services is an important way to increase their affordability, especially for poor countries. Low cost alternatives, such as satellite communications, and wind and solar power, do exist in some cases. Even the costs of feeder roads can be contained by encouraging greater use of animals and bicycles for local transportation, while building roads to match. Past difficulties with the maintenance and upkeep of rural infrastructure need to be addressed through greater local ownership of investments and devolution of maintenance responsibility to communities and local government. Local incentives can be enhanced by tying investments from central government to matching funds from local district level sources.

Strengthening public institutions that provide public goods and services can also lead to significant cost reductions while improving the quality of services provided. New innovations may be needed. For example, increased donor support of key public sector investments could come from new financing arrangements that empower the users of public services (e.g. vouchers, user fees and other co-financing mechanisms) and with appropriate institutional reforms to improve mandates and performance. There is also need to form new partnerships between the public, private and NGO sectors for the provision of public services. Even though government must pay for many of these goods and services, it does not mean that the public sector has to deliver them. Recent years have seen considerable success in using NGOs and CBOs to deliver targeted assistance to the poor, and private firms can be contracted to build and maintain schools, health centers, roads and the like. Contracting out arrangements with other parties can be much more cost effective, and may offer better possibilities for involving local people and communities. The types of partnerships desired will vary by sector and function, with many more opportunities to diversify supply arrangements for education and health services, for example, than provision of rural roads and market regulation (Siamwalla, 2000).

Effective public institutions also require an adequate supply of trained people, including agricultural policy advisors, agricultural researchers and extension workers, business managers, and financial and computer experts. Past investments in training did help increase the supply of some types of key personnel, despite the fact that many did not return from overseas training. But HIV/AIDS, ageing, and low salaries and

morale within public institutions have contributed to chronic staff shortages in many countries.

5. Conclusions

Infrastructure and rural services are central to agricultural development. Improved infrastructure and rural services not only expand opportunities for growth, but also help ensure that such growth is more diffused and equitable. Many developing countries, especially in Africa, still have woefully inadequate levels of rural infrastructure and human capital, and this is a major constraint to their development.

Despite this importance, many governments and donors have slashed their levels of investment in rural areas in recent years. This paper has shown that this trend is misguided; many public investments in rural areas still give very favorable rates of return even in countries like India and China that have already invested heavily in their rural areas. Moreover, they also make important contributions to reducing rural poverty. The results presented in this paper show that investments in agricultural research, rural roads and education are the best win-win investments in India and China, contributing the most to both agricultural growth and rural poverty alleviation. It has also been shown that targeting more investments towards less-favored areas could also be a win-win strategy in some two countries.

There is scope for doing better with existing levels of public investment by targeting more precisely the available funds towards investments that are win-win for growth and poverty alleviation. The results presented in this paper provide useful guidelines for such targeting. But developing countries also need to improve the efficiency with which most of their public goods and services are supplied. This will require institutional reforms, new forms of financing arrangements, and partnerships with the private and NGO sectors. Governments and donors also need to step up their levels of investment in rural infrastructure, technology and human capital, especially in Africa. These investments are essential for the successful agricultural transformation of these countries.

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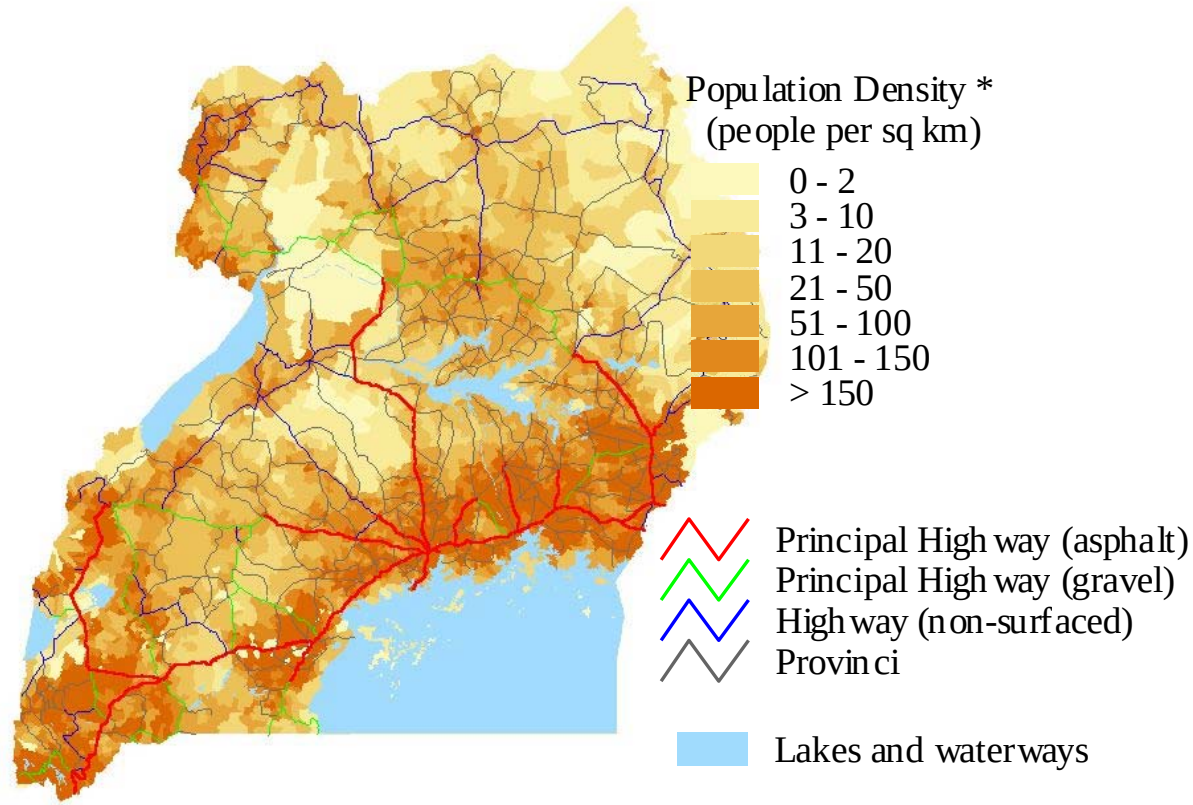
Figure 1: Population Density and Road Network in Uganda



Source: Density, Gerd Rueker (2001) based on Uganda Bureau of Statistics 2000 Statistical Abstract (June 2000); Roads, WRI 1998

Liberalization of Food Markets in Benin. A Plea for Social Capital and a Rigorous Anti-Trust Policy.

Clemens Lutz

1. Introduction

During the last decade extensive economic reforms were undertaken in the agricultural sector in Benin and in many other countries in Sub-Saharan Africa. The reform efforts have generated a positive response, however the results have generally not met expectations and much remains to be done (Kherallah et al., 2000). Thorbecke (2000) distinguishes two types of liberalization policies. Policies that focus on getting the prices right (devaluation, abolishment of tariffs, elimination of state commodity boards) and policies that have a wider scope: trade liberalization policies together with a constellation of structural measures designed to improve the functioning of markets. The latter policies could be described as getting the prices and institutions right: "a comprehensive and joint package of policy measures addressing institutions and other initial conditions to relax the constraining effects of binding elements is a sine qua non to the successful performance (…..) of cash crops as well as of staple food markets. Pushing the price button in a setting where one or more complementary measures or conditions are absent is fruitless" (ibid, p. 40).

A number of recent articles (e.g. Fafchamps and Minten, 2001a, Knack and Keefer, 2001) stress the importance of social capital for the reduction of transaction costs. This argument is relevant for food marketing channels in developing countries. In many of these countries the food markets are operating in a weak institutional environment where institutions are deficient or cannot be enforced by the "soft state". The small-scale of most of the transactions further constrains the effectiveness of existing formal institutions (e.g. McMillan and Woodruff, 1999, Fafchamps and Minten, 2001b). In these circumstances (social) relationships are very important for traders and it is expected that social capital contributes to the creation of enforceable institutions. More in general, it can be noted that the role of trade relationships has been a major issue in the literature on industrial organization: for example, many authors stressed the importance of business networks for efficient transactions (Hakansson and Snehota, 1995, Ghauri et al., forthcoming).

The purpose of this paper is to show how food-marketing channels in Benin are organised and how reductions in marketing costs can be realized. In particular in economies in transition this is relevant, as new organizational structures have to be developed. The marketing channels approach and the theory of institutional economics provide a useful framework for the analysis. The paper wants to make a nuance in the debate on the importance of social capital for the functioning of food-

markets in developing countries. In a recent study Fafchamps and Minten (1999 and 2001) show that traders with more relationships (social capital) realize higher output. They conclude that the accumulation of social capital should be fostered (ibid, 1999, p.31). In the debate on food trade policy in Benin these results have been a support for a project that facilitated local trader organizations (Alapini, 1999). The results of this project were evaluated positively by Gabre-Madhin, et al. (2001): "Another positive factor is the prevalence of trader associations in Benin and the strong public support that they are accorded". However, experience with this policy shows that the major objective of these local organizations is the protection of the interests of incumbent wholesalers. The unconditional support for local organizations will hamper the dynamic efficiency in the market and will create a bottleneck for further organizational change.

The paper is structured as follows. Section 2 will present some major reasons for persistent market imperfections in many food markets in developing countries. Section 3 focuses on marketing channels and institutions. Section 4 discusses the organization of food marketing channels in Benin. Section 5 argues that institutions play a dominant role in the organization of the private food market and discusses some opportunities for reduced costs. Finally, Section 6 shows how local trader organizations may constrain organizational innovations.

2. Food allocation by the private market: an overview of a debate

The quest for improvement of the functioning of food markets is a major policy issue in many developing countries. Properly functioning markets will serve both the producers at the one end of the marketing chain and the consumers at the other end. Food market performance is the result of a complex set of institutions (formal and informal rules) which co-ordinate exchange and initiatives undertaken by individuals (traders, farmers) governmental and non-governmental organizations (cereal banks, co-operatives). Views on the performance of food markets in developing countries have shifted in the course of time. During the 1960s the debate stressed the existence of "market failures": due to a lack of competition traders were alleged to abuse their market power; a lack of capital and credit were supposed to constitute an entry barrier for small traders and due to a lack of information, market integration was expected to be deficient.

Interventionist policies were developed to correct for these failures. However, the experiences in the 1970s have shown that many of the so-called "market failures" were only replaced by "government failures". Ellis (1992) summarises the government failures as follows:

- Information failures:
  It appeared almost always wrong to assume that state officials have any clearer idea of the supply and demand conditions in the market than private sector operators. This resulted in serious misallocation and the coexistence of a network of formal and informal parallel markets.

- Complex side effects:
  Interventions have secondary effects in an economy, e.g. maximum consumer prices may lower farm-gate prices or increase government budget-deficits.

- Implementation and motivation failures:
  Most of the developing countries are "soft states" with "soft bureaucracies", making the implementation of market policies all over the country's territory a difficult task. Moreover, low salaries affect the motivation of the civil servants in charge.

- Rent-seeking:
  Under the above-mentioned conditions state action may easily lead to bribery and malpractice.

As a result of the experiences in the 1970s, structural adjustment policies in the 1980s and 1990s advocated market liberalization. These have put to an end the interventionist policies of many governments. The new market policies claim to foster the functioning of the market. However, in spite of the liberalization, several market imperfections (market failures) persist and the costs involved in market transactions are high. Some of the major imperfections can be summarised as follows:

- *Seasonal and spatial arbitrage with imperfect information*

There is no synchrony between food production and food consumption. In the semi-arid areas rain fed production systems have only one harvest a year, while consumption is continuous. Moreover, harvests are

regularly threatened by climatic hazards: yields are volatile. This seasonal aspect may cause substantial price fluctuations, as storage costs (due to storage losses and capital needs to finance the cereals) are important and information on local supply and demand conditions is imperfect.

On a perfect market, prices convey information from households to firms concerning what consumers want, and from firms to households about the production costs (Stiglitz, 1994:8 and 1986). In most of the developing countries this information is difficult to obtain as the telecommunication infrastructure is imperfect and local market rules are non-transparent. In many cases information depends on personal networks of individual traders. In order to safeguard their existing trade relations, traders are reluctant to share their information with competitors. Some information simply does not exist due to risks in the production process. Other sources of information may exist but are not always accessible for all traders and farmers. Moreover, in many countries official regulations are not transparent and their implementation arbitrary. These conditions restrict competition, as a lack of information constitutes an entry barrier. The existence of oligopolistic markets often seems to be based on the possibility for certain wholesalers to detain specific information. In practice we observe that many traders stick to their individual marketing networks, which are nested in particular geographical regions.

- *Thin markets*

Many producers are peasants who are to a large degree self-sufficient with regard to food (Matthews, 1986). Often they buy/sell incidentally their deficit/surplus in the market. The grain stock is perceived as a liquid source that may be used for urgently needed household necessities. The problem for the market is that many of these transactions concern small and highly variable quantities, scattered all over the country's territory. This fragmented structure inflates transaction costs: the assembly and distribution of cereals becomes a labour-intensive and costly activity. Another effect induced by thin markets is that small marketable surpluses also restrict competition among traders (in particular wholesalers may profit from a local monopsony), as only a limited number of traders are sufficient to drain the surplus.

- Missing or Incomplete markets

In most developing countries, the set of commodity and service markets is highly incomplete (de Janvry et. al., 1991). Imperfections in three related markets, providing essential services for cereal trade, hamper the functioning of the food market and increase the transaction costs:

- Transport services are only available to a limited extent. In most countries a small group of large-scale wholesalers have their own transport facilities, but the majority of small-scale traders depend on public transport facilities, which are mainly oriented toward the urban centres. During rainy seasons large rural areas may even become inaccessible. Consequently, the transport of commodities is less flexible than required for optimal trade flows.

- Credit facilities constrain the commercial activities of traders and farmers, in particular the storage function. Often the formal financial sector does not provide credit for trade activities and even if credit facilities do exist, most traders and farmers lack the necessary collateral (see Zeller et al., 1997). The upshot is that most traders operate with very small funds and most farmers have little withholding capacity (they need money to settle debts and household expenses).

- Finally, an insurance (harvest failures) and futures (hedging) market, accessible for individual traders and farmers, does not exist. Hedging against price fluctuations is impossible. The institutional structure necessary to guarantee the enforcement of contracts on the futures and insurance market is weak, and this results in the non-existence of this market.

- Hostile and Unstable Policy Environment

In the 70's market imperfections were generally taken responsible for all kind of marketing problems. Several populist regimes concluded that traders abused their alleged market power. All kinds of controls were installed to restrict the behaviour of traders. Despite the plea for liberalization since the 80's, many controls exist to date. Many traders prefer to save on the costs of formal taxes and pay some money to bribe controlling agents, who are not so much interested in checking whether the formal taxes are paid but more interested in topping up their salaries. Corruption, differences between local and national policies, changing tax

laws, general mistrust of traders are all elements that provoke a hostile environment for traders (see also Smith and Luttrel, 1994). Taking into account the amount of money involved in a truck loaded with food, the effects of this hostile environment should not be underestimated. It increases the risks for traders and may constitute a real entry barrier for potential newcomers on a local market. The upshot is an unstable, opaque institutional environment, which hampers the market and the furthering of institutions that reduce transaction costs.

3. Marketing Channels and Institutions

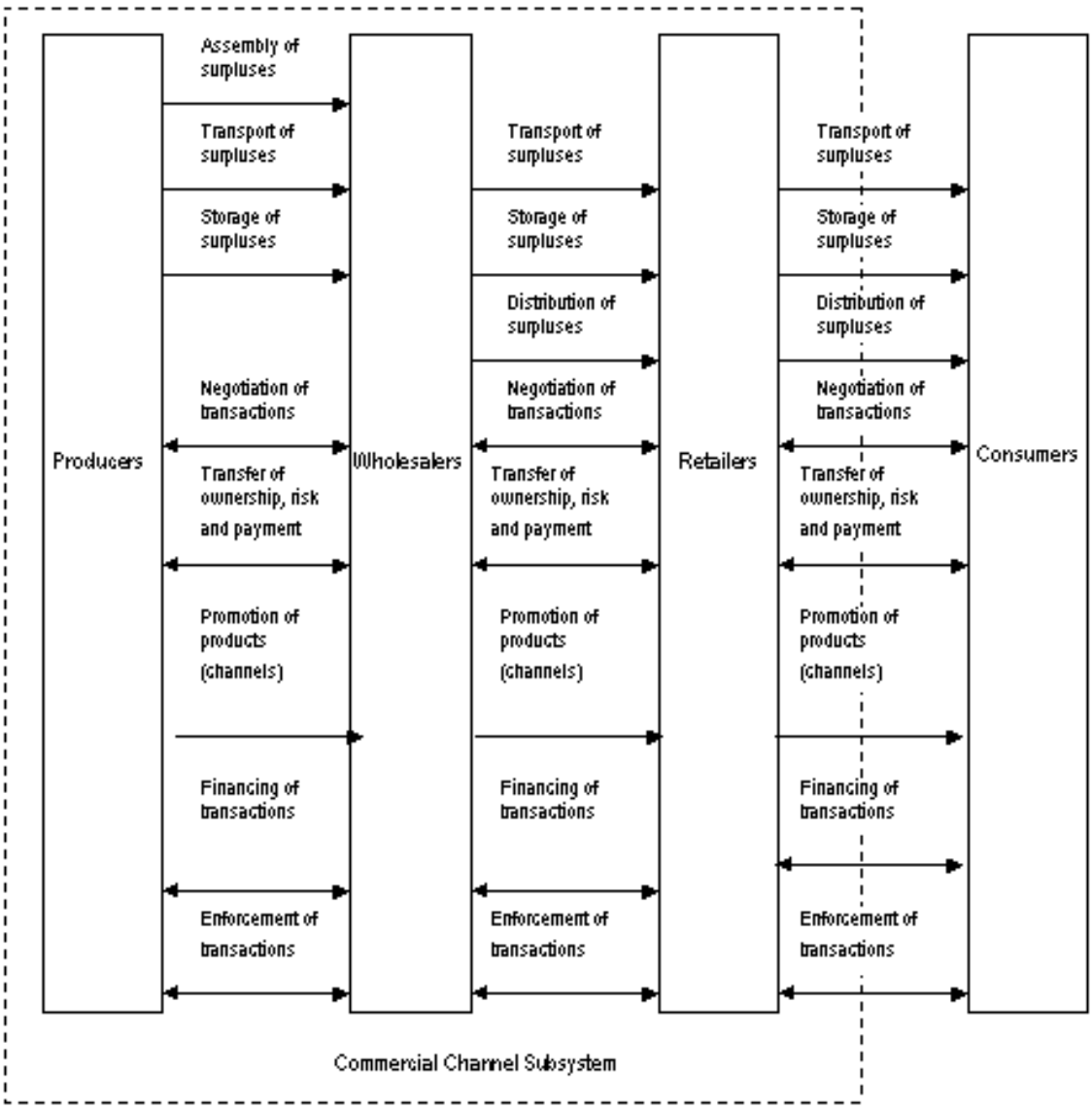
The above-mentioned problems influence the functioning of the food marketing channels.
Marketing channels consist of a number of intermediaries all involved in making the product available for the final consumer (see Coughlan et al., 2001). In Benin most transactions take place in conventional marketing channels. These channels rely heavily on spot markets where commodities are traded between actors who are not involved in recurrent trade relationships. Figure 1 shows how complicated transactions in a simple conventional food marketing channel are if all partners are involved in all the functions. The following functions are distinguished:

1. Assembly of surpluses:
   Thin markets and seasonality make this function rather complex and exemplify the importance of access to proper information in Benin. The market information system is not operational or trusted and information is exchanged mainly within personal networks.
2. Transport of surpluses:
   As the large majority of food traders do not have their own means of transport they hire this service on the market for public transport. As rural markets are thin, availability of these services is not always guaranteed.
3. Storage of surpluses:
   A lack of modern infrastructure, instable climatic conditions and missing futures markets, imply that uncertainty and high costs characterise the execution of this task.
4. Distribution of surpluses:
   Thin markets and seasonality make this function rather complex and exemplify the importance of access to proper information.
5. Negotiation of transactions:

The lack of standard procedures (units of measurement and quality standards) is a nuisance for transparency in the market.

6. Transfer of ownership, risk and payment:
   As long as transactions take place in conventional channels this is not a problem as these are characterised by cash payments and direct delivery. However, transactions in vertically integrated marketing channels may reduce costs, but need more institutional support. To date “the play of the game” is based on trust and this limits the opportunities for vertical integration.
7. Promotion of products (channels):
   This function is limited to cleaning of the product and controlling for freshness. One of the advantages of vertical channels is that promotion of the product through standard packing procedures and standard qualities can be more easily developed.
8. Financing of transactions:
   As indicated above the formal credit market is incomplete or missing. Moreover, to date the banks play only a limited role in the transfer of money. This hampers transactions that take place in vertical marketing channels.
9. Enforcement of transactions:
   See function 6

Figure 1: Functions in a conventional marketing channel



Institutions may accommodate some of the abovementioned problems and facilitate the execution of the functions presented in figure 1. Institutions are humanly devised constraints that structure political, economic and social interaction (North, 1991). They consist of both informal constraints (sanctions, taboos, customs, traditions and codes of conduct) and formal rules (constitutions, laws, property rights). Institutions form the incentive structure of a society and can be interpreted as a set of rules. Economic institutions are the underlying determinants of economic performance and shape the organization of market transactions. Williamson (2000) distinguishes 4 types of institutions:

level 1: informal institutions resulting from the social context
level 2: formal institutions defining the rules of the game in the market
level 3: institutions defining the play of the game in the market
level 4: institutions defining resource allocation inside the firm

Level 1 consists of institutions embedded in the social context like customs and religion
Economists take these rules often as exogenous factors in their analysis. These rules change only slowly. However, they are important and influence the nature of economic transactions. Level 2, concerns institutions that define the rules of the game. In particular the economics of property rights addresses these type of issues. It concerns the formal rules of the game, imposed on the market and often enforced by the government or market authorities. Economists are highly involved in this field as these rules should facilitate economic transactions and have to be respected by all actors in the market. Therefore, level 2 also influences the rules that are elaborated on lower levels in the hierarchy of economic institutions. The institutions on level 3 define the play of the game. These are the specific rules defined by the actors involved in a transaction, in bilateral formal or informal (oral) contracts. The institutions on this level define the governance structures for transactions through markets while taking into account the rules defined at higher levels. These rules facilitate market exchange between the actors involved in a transaction. Finally, the institutions on level 4 co-ordinate internal allocation, or transactions inside the firm.

The second order is the institutional environment, enforced by the state or a formal market authority. These rules should lead to efficient transactions from a societal point of view. The important task for the government is to define the rules that have to be respected by the actors in the market and, subsequently, to enforce these rules in order to guarantee that the market is a level playing field. As we are mainly interested in the organization of market transactions between actors in a marketing channel, the third level is the most important group of institutions that shape the transactions in marketing channels. Here we find the concrete contracts that define the conditions on which the transaction is based and the responsibilities of the partners involved. These contracts differ in time and space and between types of intermediaries. The contracts specify the functions that have to be executed by the partners involved. In conventional marketing channels this is relatively straightforward, however more complex contracts will

be developed when it concerns vertical marketing relationships. For example, a futures contract between a maize miller and a farmer is more complex than a contract based on immediate delivery and cash payment. Existing marketing channels should be able to co-ordinate both types of transactions in an efficient way and should be flexible in the sense that they adapt easily to new opportunities in the market.

Social capital will influence the institutions on all four levels. The development of civil society and, subsequently, the creation of new social capital will influence the rules that are set by the social context (e.g. the market should serve local food security). Some of these rules may be formalized on level 2 (e.g. in order to guarantee local food security local market authorities may restrict the 'export' of the local marketable surplus to maize deficit areas), while new institutions may be created to govern exchange relationships between actors in the market (e.g. changes in the social context may facilitate horizontal co-operation or vertical integration).

Institutions do not only define the rules, but implicitly also determine the costs of transactions through the allocation of property rights and influence the organization of marketing channels. It is here that the economics of transaction costs becomes interesting (Williamson, 2000). Three types of costs are often distinguished. The costs of obtaining information before concluding a contract (contact), the costs involved in negotiating a contract (contract) and the costs involved in enforcing a contract (control). The efficient outcome is to minimise the sum of production and transaction costs for the product or service concerned. Williamson claims that this process operates in the commercial world: that transactions do get organised in efficient ways. However, this is a much debated issue as a lot of research shows that markets operate in more or less inefficient ways. The work of North (1994) is interesting here as he shows that institutions do not necessarily evolve in the direction that facilitates the optimum organization: "Creating the institutions that will alter the benefit/cost ratios in favour of co-operation in impersonal exchange is a complex process, because it not only entails the creation of economic institutions, but requires that they be under girded by appropriate political institutions" (ibid, p. 365).

In the literature marketing costs and transaction costs are regularly mixed up. In order to prevent confusion about the concepts used it is important to make a subtle distinction between marketing costs, transaction costs and transformation costs: "Transformation costs are the costs of land,

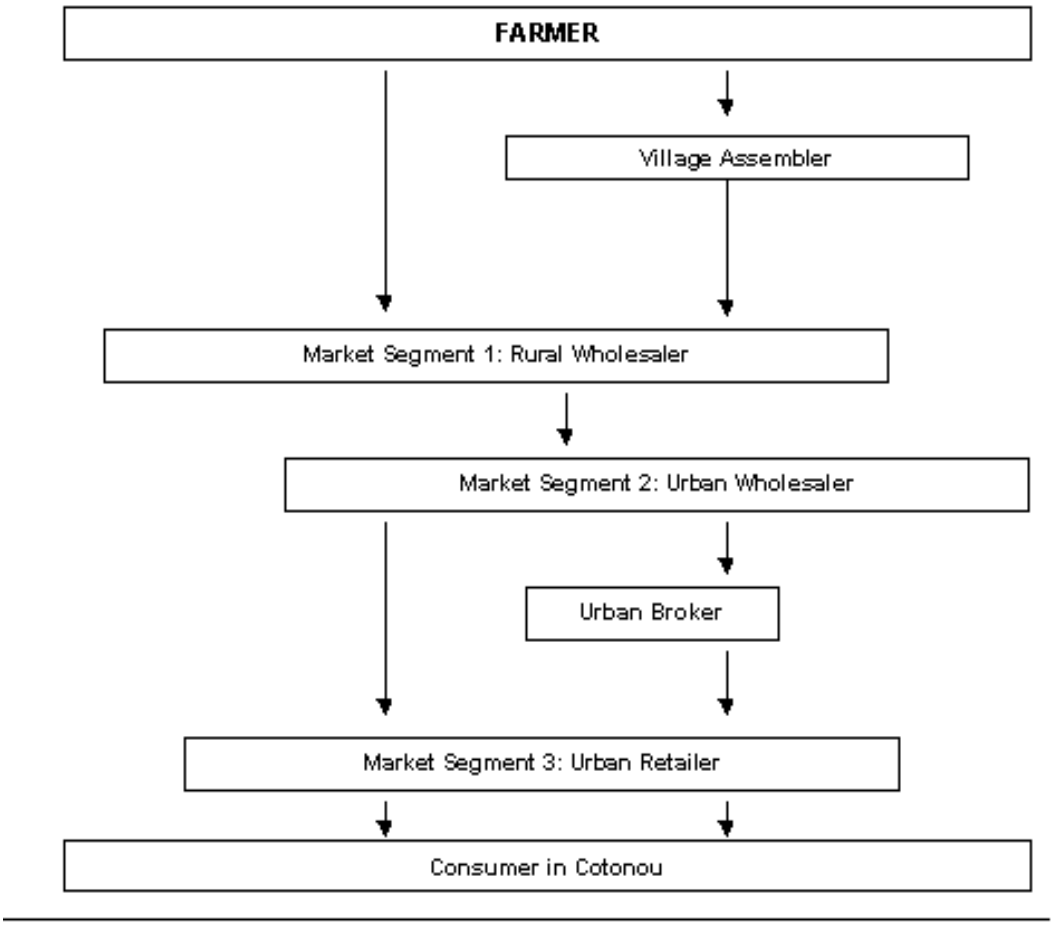
labour, capital, and entrepreneurial skills required to physically transform inputs into outputs. Transaction costs are the costs of the land, labour, capital, and entrepreneurial skill required to transfer property rights from one person to another" (North, 1994, p. 612). The functions distinguished in Figure 2 all entail marketing costs, which encompass all costs supported in the marketing channel between production of the commodity and the final customer. Following the definition for transformation costs, transport, storage, processing are treated as transformation costs, since they change a physical attribute of the good (location, time, form). The other functions involve transaction costs: assembly, distribution, negotiation of contracts, transfer of ownership and payment, promotion of products, distribution of risks, financing and enforcement of transactions. The latter functions are all related to the transfer of property rights.

4. Interregional Food Marketing Channels in Benin

Despite the problems discussed in Section 2, private food marketing channels are effective in most African countries. In order to understand the functioning of the food market we will give a closer look at some major marketing channels in Benin, connecting 2 major surplus regions: Nikki and Kétou, with the major urban centre: Cotonou (Figure 2).

The structure of the marketing channel through which the product passes from producer to consumer varies; the channel can be longer or shorter, depending on the distance and the behaviour of actors (traders, farmers, consumers) in the market. Informational problems cohere with distance; therefore we focus on inter-regional arbitrage and the costs involved. The existence of a number of alternative channels is interpreted as a positive sign because it enables farmers and consumers to choose between the appropriate marketing services needed. The choices to be made demonstrate the importance of information: where to buy or sell? Where to obtain the required quality class(es)? What is the ruling market price? Are there other, more profitable markets? Which marketing services are provided at what costs?

Figure 2: Alternative inter-regional marketing channels for maize



A result of the above-mentioned characteristics is that transaction costs are high and that market integration is imperfect (Kuiper et al., 1999). We present the results of a study carried out in Benin in 2001 in order to shed some light on the costs that market exchange provokes.

Conventional marketing channels rely on spot markets. Transaction costs are specified for two marketing channels between two rural and the major urban market place: channels over a relatively short distance (Kétou-Cotonou) and a long distance (Nikki-Cotonou) are distinguished. Most farmers sell the marketable surplus to assemblers or wholesalers on the village market. They transfer the food to wholesalers in the regional market. Urban wholesalers collect the surplus on the regional market to supply the retailers or processing firms in Cotonou. Two types of channels are distinguished on the market segment that links the regional and the urban market: small-scale urban wholesalers and large-scale urban wholesalers. Small-scale

wholesalers are able to integrate the distribution function, while large-scale wholesalers have to sell through the intermediary of brokers in order to realize sufficient turnover. The table shows that small-scale wholesalers can compete with large-scale wholesalers if the distance between the local and the urban market is not too large. These channels cover the major maize flows between the markets under study and represent the principal types of market intermediaries. The retailers sell in the retail-segment directly to consumers. Retailers deliver an extra service (selling in small units at specific locations) and this justifies a higher selling price.

The marketing costs involved in spatial arbitrage are considerable if compared with the average selling prices. For example, the average wholesale price in Cotonou in 2001 was about 100 Fcfa per kg. We note that, in order to simplify the analysis, storage costs are excluded from the analysis. As most traders are not involved in storage and prefer a high turnover of their stocks, this simplification is justified (see Lutz, 1994).

Table 1: Breakdown of marketing costs for 2 marketing channels: Kétou-Cotonou (short distance, 106 km) and Nikki-Cotonou (long distance, 529 km)*

	KÉTOU-COTONOU				NIKKI-COTONOU			
	Channel 1		Channel 2		Channel 1		Channel 2	
	abs	%	abs	%	abs	%	abs	%
Rural Wholesaler								
Local freight	5.0		5.0		5.0		5.0	
Gross margin	5.0		5.0		5.0		5.0	
Subtotal	10.0	29.2	10.0	29.5	10.0	26.5	10.0	23.8
Urban wholesaler	*'large-scale'*		*'small-scale'*		*'large-scale'*		*'small-scale'*	
Taxes wholesale	3.0		3.0		2.8		*2.8*	
Freight (bag)	6.9		7.7		10.3		*11.5*	
Transport trader	0.2		1.0		0.6		*5.5*	
Broker	2.9		0.0		2.9		*0.0*	
Others	1.2		1.2		1.2		*1.2*	
Gross margin	4.0		5.0		4.0		*5.0*	
Subtotal	18.2	53.2	17.9	52.8	21.8	57.7	26.0	61.9
Urban retailer								
Taxes retailer	1.0		1.0		1.0		1.0	
Gross margin	5.0		5.0		5.0		5.0	
Subtotal	6.0	17.5	6.0	17.7	6.0	15.9	6.0	14.3
Total	34.2	100	33.9	100	37.8	100	42.0	100

** Channel 2 = small-scale wholesaler buying and selling +/- 1,000 kg on the regional market per market day. Both wholesalers provision retailers. Taxes are equal for each type of intermediary. Large-scale wholesaler (channel 1) may negotiate a discount of 10% on freight costs. Large-scale wholesalers buy with the help of an assembler and sell with the mediation of a broker. Small-scale wholesalers sell directly to retailers. Traders' gross margins (according to their own estimation) vary as a rule from 0 to 10 Fcfa per kg. We imputed a gross margin of 5 Fcfa per kilogram as a normal mark-up (4 Fcfa for the large-scale wholesaler).*

Source: Lutz 2001

The costs borne by traders consist above all of variable costs; taxes, freight and commission fees. Only transport costs of the trader himself are independent of the quantity traded per trip; a quasi fixed cost. The fixed costs are more difficult to calculate; as trade concerns mainly small-scale buying and immediate reselling, most traders do not invest in fixed capital like a truck, a store or equipment. Transaction costs

such as obtaining information, enforcing and concluding (bargaining) a contract are difficult to isolate. As trade is transferred through conventional marketing channels, these costs consist mainly of costs to develop a network: search for new clients, search for peers who want to co-operate on the basis of mutual interest, search for contacts with officials in order to reduce taxes. These costs can be considered as sunk costs. Especially large-scale traders can invest in these activities, as the costs of failure can be spread out over a relatively large turnover. Small-scale traders will be more inert, as a failure implies that the dead-weight loss has to be captured on a small turnover. Consequently, their networks are smaller and more often depend on relatives and friends.

The sunk costs are limited and included in the gross margin of a trader; a remuneration for invested capital, management and risk. These components are difficult to separate and traders are reluctant to give detailed information on these issues. In order to get an idea of the average gross margin we asked traders to estimate the “normal” mark-up. This estimate was used as a proxy for a “normal” gross margin and enabled the calculation of the total marketing costs. The gross margins given by the traders vary and depend on local market conditions and the commercial services provided. However, the average figure given in the table can be interpreted as an average remuneration, necessary to attract the interest of the trader in the activity.

5. Opportunities for reduced costs and new market institutions

An efficient channel reduces transaction costs to a minimum by involving only these actors who have a comparable advantage to execute specific functions (producer, wholesaler, retailer, consumer, transporter, broker). Conventional channels follow a strict procedure: all channel partners are involved in all the tasks. However, some traders are quite active in developing alternative marketing channels. Basically they can follow 4 strategies to reduce transaction costs:

1. Avoiding payment of formal market taxes;
   Tax payments are reduced if the product does not pass through formal market places. We observe that formal taxes constitute a significant part of the trader's commercial gross profit: for urban wholesalers in a conventional marketing channel this tax element is approximately 60% to 80%. This shows that passing through the

informal market is encouraged by the tax levels and explains why the majority of flows are not taxed according to law. It also explains why local governments, in co-operation with local traders, regularly discourage integrated vertical channel arrangements, as these channel formats reduce their revenues or hamper tax collection (see the next Section).

2. Increase of turnover per trip in order to reduce transport costs;
   The structure of transaction costs given in Table 2 shows that for long distance trade an increase in turnover per trip may reduce marketing costs. This explains why traders try to increase volume. However, taking into account seasonality of production, imperfect information and transactions based on conventional marketing channels, the required minimum quantities can only be found during the harvest season. Consequently, the small-scale wholesaler is the most regular intermediary in the market.

3. Eliminating brokers and/or retailers in the chain;
   The establishment of selling networks facilitates the flow of information and may reduce the number of intermediaries in the channel and, subsequently, may lead to cost reduction. For example, wholesalers may work out a strategy based on the availability of production factors (capital and labour), know-how and relationships. This explains why some urban wholesalers specialise in selling networks and prefer to buy from rural wholesalers.

4. Eliminating assemblers and/or local wholesalers in the chain.
   The establishment of buying networks will provide traders the necessary information on local supply conditions. Again, wholesalers may work out a strategy based on the availability of production factors (capital and labour), know-how and relationships, to reduce the number of intermediaries. This explains why most rural wholesalers in Nikki and Kétou specialise in buying networks and prefer to sell on the regional market to traders from Cotonou.

The examples show that some traders develop strategies to eliminate intermediaries. This implies that functions have to be assumed by other members in the channel: some type of vertical integration has to be achieved and new institutions (level 3) have to be developed. For example, cost reductions are possible if transport costs to the ‘intermediary’ market can be saved through direct delivery to the urban

market and if net margins of obsolete intermediaries are eliminated. However, there is a trade-off between flexibility and integration. Moreover, if the institutional infrastructure is weak, integration may become risky, which makes traders reluctant to expose themselves to opportunism (see also Fafchamps and Minten, 2001b). This explains why most transactions take place in conventional marketing channels. It also supports the argument that social capital may facilitate the creation of business networks.

Finally we observe that primary assembly is determining an important part of the total marketing costs. The lack of information on supply, the small quantities per transaction and the accessibility of the farms (condition of rural roads) explain these costs. This may be interpreted as an argument for stronger involvement of farmers in primary assembly. They have the information on supply and they can regroup the marketable surpluses in larger quantities. Therefore it is remarkable that farmer organizations are not active in vertical marketing channel arrangements in Benin. In the past, this resulted from government top-down policies that encouraged farmers to sell their surpluses on the local formal market. This policy was expected to increase competition among traders on spot-markets and to protect isolated farmers. Another argument for this policy was that it facilitated the levying of local taxes. Consequently no support was given by the extension service to farmers that wanted to develop commercial strategies.

The cost structure shows that an important opportunity for better farm prices may be rooted in the commercial functions assumed by farmers or farmer organizations. Taking into account the high assembly costs, farmer organizations may have a comparative advantage for the execution of this task: they may perform the task of the local assembler and the local wholesaler. Moreover, farmer organizations may facilitate the storage process and improve access to credit. These organizations may also facilitate the learning process of commercial skills. With further developments in the telecommunication system farmer organizations may even replace urban wholesalers and sell directly through brokers in the urban market. This is not to say that farmers are easy to organise and that the transaction costs involved in these organizations can be neglected. However, the non-involvement of farmers in food distribution looks like a missed opportunity for increased farmer' revenues. The question arises why farmer organizations are not more active in vertically integrated marketing channels in the liberalized food market in Benin.

6. The role of local social capital: a barrier or a stimulant for organizational change?

The actual enforcement of rules in networks is often based on trust. Formal legal procedures are too expensive to provide protection for the interests of the partners involved (Fafchamps and Minten, 2001b, McMillan and Woodruff, 1999). Trust may be a solution for this problem but the inconvenience is that it takes a lot of time to establish it in a weak institutional environment. A lack of trust constitutes a barrier for vertical integration in the food-marketing channel. Social capital is expected to facilitate trust building and business relationships. In many food markets trader organizations are developing institutions to facilitate market functioning: "The associations are sophisticated "Coase-like" responses to this market environment: they focus on reducing their members' transaction costs"(Luttrell and Smith, 1994). However their dimensions are often restricted to the local formal market place and they are strictly guided by their self-interest. Therefore control for collusion and artificial entry barriers is important.

Social capital is not a straightforward concept (see Knack and Keefer, 2001). Narayan and Pritchett (1999) defined it as follows: the quantity and quality of associational life and the related social norms. The problem is how to measure the concept of social capital. Putnam (1993) used membership in formal groups as a proxy for this capital. In order to be able to measure the value of social capital on the firm level, Fafchamps and Minten (2001a) use 'the number of traders known' as a proxy for social capital. They interpret the number of contacts as a variable that improves market information and trust. The first question that arises is 'what is meant with knowing other traders?'. How did traders interpret this question: how many traders do I know personally, or, with how many traders do I deal on a regular basis, or, how many faces do I know? Moreover, the number of traders known is not necessarily a proxy for quality of information: a wholesaler buying through assemblers and selling through brokers may have a limited number of recurrent business contacts that provide trust and proper market information.

A more serious problem is that traders in marketing channels are involved in different functions on different segments in the market and that not all traders are able to perform the same functions (see Figure 1). For example, limited access to capital is a barrier to entry in the

wholesale segment. Due to the fact that the capital market is not perfect small-scale traders simply do not have the capital to enter the wholesale market. Consequently, they have to restrict their activities to some specific commercial functions: retail trade and local assembly. Due to the local nature of these transactions it can be expected that a limited number of contacts with wholesalers will suffice to be successful. This implies that the correlation between output and scale, observed by Fafchamps and Minten, can be spurious. They did not distinguish assemblers, retailers and wholesalers (50% of the interviewed traders in Benin are retailers, see Gabre-Madhin 2001, p. 9). Large-scale traders may be more productive simply because they carry out other functions than small-scale traders. The activities of the latter group are restricted to petty trade, which is characterized by fierce competition and, therefore, not interesting for large-scale traders. The same argument was put forward by Barrett, observing that most traders do not have access to the equipment and credit required to penetrate the more profitable segments of the food market in Madagascar (cited by Fafchamps and Minten, 1999, p. 4).

The question arises whether large-scale traders have higher profits due to the larger number of contacts or due to the fact that they perform more profitable functions in the channel? Subsequently, it becomes interesting to know why wholesalers are able to realize higher margins, or, how they reduce competition on their market segments. The experience in Benin shows that social capital may provide the answer.

Since 1996, the national board for food security in Benin (ONASA), carries out a project to organize food traders. These initiatives were supported by several research results. For example, Tassou (1995) concludes that the trader organizations do not hamper the functioning of the market and do not lead to excessive profits. Gabre-Madhin et al. (2001, p. 113) support the policy to promote market institutions such as trader associations and intermediation services. Three regional organizations were established, and these organizations were expected to represent the wholesalers on the local markets. The objectives of these organizations were rather ambiguous: e.g. contributing to food security, encouraging traders to registrar their firm, and protecting the interests of the members. Due to the fact that the national objectives were not always in line with the local priorities, these regional organizations have not met expectations. However, on the local level in Nikki and Kétou some strong organizations were created. To facilitate transactions warehouses were built on the market place by ONASA

and the management of these buildings was delegated to the local trader organizations.

The positive effects were that local traders organized some sessions to train their members in storage techniques, bookkeeping, etc. Moreover, the local organization plays a role in conflict resolution and the development of local standards for measurement. However, all the activities have been subject to the primary goal of protecting the interests of the local incumbent wholesalers. Two groups of stakeholders complain about the situation: farmers and non-resident wholesalers. Farmers taking commercial initiatives are harassed and non-resident wholesalers, willing to buy directly from farmers, are fined by the local trade organization. This shows that the trader organizations simply prohibit the development of integrated marketing channels: the major source for further reductions in marketing costs. Moreover, we observed that the local authorities approve this behaviour, as it is part of the policy to facilitate local trader organizations (see also Tassou, 1995, p. 48 and Fanou et al., 1991).

The result is puzzling: some types of social capital can reduce marketing costs, while other types of social capital can inflate the costs. The concept of “Social Capital” is ambiguous. Some forms facilitate transactions, while others hamper efficient trade relationships. In order to assess the effects of different forms of social capital it is important to have a good understanding of the organization of the marketing channels, the structure of the market and the behaviour of incumbent traders. In line with this argument, Knack and Keefer (2001, p. 1284) noted that “promoting horizontal associations may be counterproductive”.

7. Conclusion

The Benin case showed the importance of getting the institutions right. Withdrawal of the government will not solve the information problem and will not protect actors in the market against artificial entry barriers. Liberalization policies that neglect the importance of a national market authority that imposes the rules of the game (institutions on level 2) may reduce the dynamic efficiency in the market. In Benin local trader organizations are preserving the present situation and, therefore, constitute a barrier for the development of integrated marketing channels. We have good reasons to expect that farmer organizations may play a crucial role in the further reduction of marketing costs.

However, the present support for local trader organizations is a serious barrier for these type of initiatives in the two rural markets under study. At least three policy initiatives are necessary to complement the liberalization process:

- A support to trader organizations can be given only on the condition that harmful cartel-arrangements are prohibited. Despite the expected positive effects of social capital there is a need to control artificial entry-barriers. In particular in a liberalized market there is a need for transparent rules of the game enforced on a national scale by a trustworthy market authority. In this respect it was remarkable to observe that all policy documents we could consult in Benin interpreted liberalization as 'withdrawal of the state'. No explicit reference was made to the crucial role of competition.

- Traders and farmers should be encouraged to improve the institutions that shape the play of the game. The development of vertical (hybrid) marketing channels that beat existing marketing channels should be facilitated.

- An operational market information system should be installed. To date the market information system is not operational on a national scale. Incumbent traders indicate that their willingness to pay for this service is limited. They rely on personal networks that provide more accurate information. However, market information in less transparent markets can be considered as a merit good. It will make market segments more contestable and it will make farmers more eager to develop commercial activities if the information is adapted to their needs.

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The effect of institutional improvements on cereal trade in Burkina Faso: infrastructure, market information, and credit

Arjan Ruijs

1. Introduction

A well functioning cereal market is a prerequisite for attaining food security, which is of great concern in Burkina Faso as in many other African countries. In this paper, the effect of some institutional improvements on the distribution of cereals over space and time and on cereal prices in Burkina Faso is analysed. In the literature on the functioning of food markets in West Africa, problems with these institutions are often perceived as a major constraint for food marketing and rural development in general.
The functioning of the cereal market in Burkina Faso has improved a lot in the last decade. This is among other things due to the adoption of the Structural Adjustment Programme in the early 1990s and the devaluation of the Franc CFA in 1994. Despite the liberalisation of the cereal market and numerous other changes many difficulties persist. Some of them are due to malfunctioning institutions or some peculiar characteristics of the cereal market in Burkina Faso. For example, cereal markets in the sparsely populated areas are thin, which means that many transactions deal only with small quantities. As a result competition is restricted and marketing costs are high. Secondly, food production is not synchronised to food consumption. There is only one harvest per year, while consumption is continuous. In the same vein, the place of cereal production usually does not correspond to the place of cereal consumption. A prerequisite for producers and traders to make efficient transport and storage decisions is that adequate information is available on prices, supply, demand, market rules, transport facilities, credit facilities, etc. This information is often difficult to obtain. Many traders rely on personal networks in order to obtain this information. Thirdly, some markets, like the markets for transport, credit, and insurance, are missing or incomplete. Such imperfections hamper the functioning of the food market and increase transaction costs.

In this paper, the effect of improvements in some of these institutions are analysed. I concentrate on the effect of improvements in infrastructure (roads and communication infrastructure), market information services, and credit facilities on cereal prices and cereal trade in Burkina Faso. Some other institutional improvements are analysed in Ruijs (2002). These effects will be analysed using a stochastic, equilibrium model in which the behaviour of the cereal producers, traders, and consumers is simulated simultaneously. Before discussing the main principles of this model in Section 3, I first briefly discuss the organisation of the cereal market in Burkina Faso. Using

this information, some scenarios can be formulated which indicate how institutional changes are expected to affect cereal trade and cereal prices. Furthermore, this information is necessary to understand some of the choices made in the model and to interpret the results of the model. In Section 4, the model is used to quantify the effects of the scenarios of institutional changes. Finally, in Section 5 some conclusions are drawn regarding the results and the model.

Cereal Trade and Marketing Costs

In this section, three scenarios are formulated which indicate how improved market institutions are expected to affect cereal trade in Burkina Faso. For this, first I briefly discuss which factors cause some of the problems on the cereal market and how. In Burkina Faso, the exchange of cereals from producers to consumers can take many different forms, depending among other things on the number of intermediaries involved. The intermediaries on the cereal market in Burkina Faso are assemblers, wholesalers, brokers, and retailers. They may purchase, collect, transport, store, and sell cereals. Furthermore, they negotiate on agreements concerning quality, delivery, price, distribution of risk, financial matters, and enforcement. The costs they make for these tasks can be classified in transport costs, storage costs, and transaction costs. The last cost type includes the expenses for the negotiation tasks and for gathering the necessary information. From a number of surveys performed in the past in Burkina Faso, it is derived that they are 5% to 14% of the price paid by the consumers. Moreover, transport costs are 5% to 20% and storage costs 6% to 9% of the consumer price (see Déjou, 1987; Sherman et al., 1987; Bassolet, 2000; Sirpé 2000 and price data obtained from SIM/SONAGESS).

The marketing costs are influenced by the state of the market institutions. These institutions are important, because they have to facilitate trade. Many problems on the cereal market in Burkina Faso are related to outdated market information, underdeveloped communication and road infrastructure, inaccessible courts, non-transparent market rules and regulations, a low degree of organisation, inaccessible capital markets, and low education levels. Due to malfunctioning market institutions, especially uncertainty and the investments which have to be made in order to set up and maintain trade relationships (posting assemblers in remote regions, development of trade skills and knowledge, collecting information, and building up relationships with clients), may lead to high transaction costs. For example, because information on trade opportunities is difficult to obtain, it is important for a wholesaler to set up an expensive network of assemblers who know local market conditions; due to expensive or

absent transport services and communication infrastructure, wholesalers often send non-qualified but trustworthy relatives to remote areas, instead of qualified strangers whose behaviour can hardly be monitored; due to the inaccessibility of courts, agreements are difficult to enforce; non-transparent market rules and missing quality and quantity standards complicate entry of new traders in a region. Many of the uncertainties and of the associated costs are related to a lack of information on trade opportunities in the future and in other regions. Especially price uncertainty is reported to be an important impediment on the cereal market in Burkina Faso.
The way transactions are organised on the cereal market in Burkina Faso are to a large extent motivated by transaction cost considerations. To reduce uncertainty on the behaviour of employees (and hence reduce transaction costs), relationships between wholesalers and their employees are often based on family or clan ties. In these relationships, trust can more easily be maintained, information can more easily be obtained, and agreements can more easily be enforced. Furthermore, reasons explaining the close ties between cereal traders and their clients are to improve market access, to reduce supply uncertainty, or to reduce transport and storage costs. Due to these motivations wholesalers invest in long-term relationships with traders on distant market places or close agreements with important farmers.

What are expected to be the effects of improved market institutions on cereal trade in Burkina Faso? I consider three scenarios of institutional improvement. First, consider the scenario in which infrastructure is improved. Due to bad road conditions transport costs are high. Better road maintenance and more asphalted roads will have a large influence on truck maintenance costs, fuel costs, and transport time. A positive effect of better roads is not only that transport will become cheaper, but also that the mobility of people and goods will increase. This indirect effect may have a stimulating effect on the economy. For wholesalers monitoring is expensive due to the bad transportation and communication infrastructure. To reduce behavioural uncertainty and transaction costs, they rely on trustworthy relatives. However, relatives are not necessarily the most qualified traders. If infrastructure would improve, wholesalers are expected to employ more often qualified non-relatives. In that case, traders without a trade network can more cheaply move to an assembly market to purchase directly from producers instead of relying on assemblers or local traders. Not only transport costs but also transaction costs will decrease for them. Purchases will probably more often be spot market transactions and less often purchases from familiar producers or traders. Note that such

an evolution can only take place slowly, because of social norms and rules which force wholesalers to hire relatives.

Secondly, consider the role of market price information. To decide on where and when to buy or sell, price information is indispensable. Currently, however, price data transmitted by SIM are often inaccurate and outdated (Bassolet, 2000). For the wholesalers, accurate price information will decrease arbitrage uncertainty and the dependence on their agents for obtaining reliable information. They can decide with less risk, to transport to regions with more favourable prices. Moreover, with more accurate price information, traders can better predict future prices. Consequently, the risk of suffering losses from storage decreases. Hence, transport and storage costs will fall. Also transaction costs will be lower. Especially the time and personnel needed to obtain the required information will reduce. The need to set up a trade network in order to obtain correct information reduces. Furthermore, it becomes easier to monitor whether agents trade at reasonable prices. The wholesaler becomes less dependent on family members, because hiring unknown employees involves less risk. As a result, trade networks may evolve from networks in which gathering information is important, to networks in which assembly and distribution of cereals is the main task. Moreover, producers, consumers, and small, independent traders will have a stronger negotiation position with the larger traders if they have more accurate price information. They can more easily choose for the trader offering or demanding the best prices. As a consequence their transaction costs decrease (one could say that their negotiation costs decrease or that the losses incurred by a bad negotiation position decrease). It is expected that more will be traded on the spot market and less with familiar traders.

Thirdly, consider the effect of improved credit facilities. The difficulty of obtaining a credit at a reasonable interest rate is one of the major problems at the cereal market. Missing credit markets prevent small traders from extending their trade network or storing their merchandise. Especially the capital costs of cereal trade are considerable. Credit facilities were promised to be set up for cereal traders after the market liberalisation. However, conditions imposed on credit granting are still too stringent for most traders. If credits can be obtained more easily, local traders can purchase larger quantities of cereals without being pre-financed by wholesalers. Consequently, wholesalers can purchase from them and do not have to set up networks of local assemblers, with all the accompanying costs and risks. As a consequence, costs associated to uncertainty on the assemblers behaviour will decrease, but negotiation costs with other

traders will increase. Moreover, farmers will not be forced to take pre-harvest loans from traders against usury interest rates if they can obtain formal credits. They will become less dependent on the few traders who offer credits, but they can sell to the traders offering the best prices. As a consequence their transaction costs will decrease. The result of these changes will be that the relationships between the different market actors will become looser. Wholesalers will purchase more from independent assemblers, rather than employing them. Farmers will choose the traders offering the best prices, rather than selling each year to the same traders. These changes will only take place slowly, due to the rigid social rules. Furthermore, competition on the cereal market is expected to improve if market actors have more freedom to choose trade partners.

In the next section, a mathematical model is set up, which can be used to analyse quantitatively the effect of the above mentioned scenarios on cereal trade and cereal prices.

A Stochastic, Equilibrium Model of Cereal Trade

Consider a situation in which a country is divided in n regions and a year is divided in T periods, from one harvest to the other. In each region is one market, numbered $i = 1,2,\ldots,n$. Markets are competitive, implying that no single agent can influence market prices. If a farmer produces cereals, part of it may be stored for home consumption, the rest is sold on the market in one of the periods $t = 1,\ldots,T$. Farmers of region i sell only to traders at market i, not at other market places, and not directly to consumers. In period t and at marketplace i, farmers get a kg-price p_{it}, called the *producer price* of region i. The total quantity of cereals sold by the producers of region i in period t is called the *producer supply* (of cereals) in region i. Consumers in region i buy from traders at market i and have to pay in period t a kg-price π_{it}, called the *consumer price*. The quantity bought by the consumers of region i in period t is called the *consumer demand* in region i. Traders in region i purchase the producer supply in this region, may transport cereals to regions $j = 1,...,n, j \neq i$, where they sell the consumer demand to the consumers, or store the supply to sell in one of the later periods.

Samuelson (1952) and Takayama and Judge (1971) were the first who analysed such a situation using an optimisation model. Ever since, these methods have been applied frequently, especially for agricultural, energy and mineral resources problems (see e.g. Takayama and Judge, 1971; Judge and Takayama, 1973; Labys et al., 1989; Guvenen et al.,

1990; Roehner, 1995; Van den Berg et al., 1996). Dealing with equilibrium on spatially separated, competitive markets, Takayama and Judge use the term 'Spatial Price Equilibrium' (SPE) for a situation where prices and quantities satisfy the following properties: 1) in each region, there is only one producer and one consumer price, p_{it} and π_{it}; 2) commodities purchased in one region will be transported to another region if the difference between the consumer price in the importing region and the producer price in the exporting region is at least equal to transport costs (Van den Bergh et al., 1996, p.50, see also Takayama and Judge, 1971, p.34); 3) commodities purchased will be stored if the difference between the consumer price in the selling period and the producer price in the purchase period is at least equal to storage costs. If a finite time horizon is considered, it is usually assumed that no stock remains after the last period. Takayama and Judge optimise in their equilibrium models 'semi-welfare', subject to supply-demand equilibrium on the market. The welfare optimal prices and quantities satisfy the properties of a SPE. Because Takayama and Judge assert that an SPE describes accurately price formation on a competitive market, they conclude that the models are suitable for analysing price formation. Why an SPE describes accurately price formation on a competitive market, usually receives little attention. In my opinion, in their argumentation why this should be the case, Takayama and Judge give one important aspect too little attention. They only consider the behaviour of producers and consumers. The other market actors playing a role in market price formation, the traders, are not taken into account explicitly. However, the economic foundations of the SPE and the equilibrium models of Takayama and Judge can be better comprehended, if also the behaviour of traders is integrated in the model.

Before discussing the design and properties of a spatial equilibrium model to analyse cereal trade in Burkina Faso in Section 0, the strategies of the market actors will be discussed: consumers, producers, and traders. These results are important in order to verify whether optimal equilibrium results are in line with individual behaviour of the market agents. The equilibrium model discussed in Section 0 takes into account three important features of grain trade in Burkina Faso: transport costs, storage costs and price uncertainty. For an extensive discussion of these elements, I refer to Ruijs (2002).

Consumer, producer, and trader strategies

Consumer strategies

Assume that in a region *i* and a period *t*, each consumer chooses a cereal consumption level which is affordable with his budget and

which gives him an optimal utility. Anticipating on the empirical implementation of the model for cereal trade in Burkina Faso, it is assumed that demand in period *t* only depends on current prices, and not on prices in previous, or expected prices in future periods. If the *given* cereal consumer price is π_{it}, and if consuming a quantity of cereals y_{it} gives utility $u_{it}(y_{it})$, (with $u'_{it}(y_{it}) > 0$, $u''_{it}(y_{it}) < 0$, and $\pi_{it} > u'_{it}(0)$) then it can be derived that at the optimal consumption level y_{it}

$$u'_{it}(y_{it}) = \pi_{it}. \qquad (1)$$

From (1) follows for each consumer the demand function as a function of consumer prices, $y_{it}(\pi_{it})$. Due to the differentiability properties of the utility function, inverse demand functions may be written, $\pi_{it}(y_{it})$. The assumptions $u''_{it}(y_{it}) < 0$, $u_{it}(0) = 0$, and (1), imply that

$$\pi'_{it}(y_{it}) < 0 \quad \text{and} \quad u_{it}(y_{it}) = \int_0^{y_{it}} \pi_{it}(\xi)d\xi \qquad (2)$$

These properties play an important role in the equilibrium model to be set up in the next section.

Producer strategies

To describe the strategies of cereal producers in Burkina Faso, an approach is followed that differs from standard supply theory. In standard theory, a producer is assumed to maximise net revenues. The net revenue function is set up in such a way that a supply function can be derived, which gives optimal supply as a function of current producer prices. In this paper, however, it is assumed that supply not only depends on current producer prices, but also on uncertain future prices.

Some general characteristics of cereal producers in Burkina Faso are that 1) a large part of the cereal harvest is consumed by the farm members and only a small part is sold; 2) annual cereal supply hardly reacts on cereal prices; 3) almost all producers, rich as well as poor, sell and purchase cereals in each quarter; these sales may be 'forced sales' to satisfy urgent cash needs (see Ruijs (2002) for a more detailed discussion of the strategies of burkinabè farmers).

On the basis of these characteristics, I assume that the amount of cereals each producer can supply in one year is equal to a fixed portion of the available cereal harvest. The size of the stock of cereals they can supply, called w_{i0} for $i = 1,\ldots,n$, is known at the beginning of the first period. The question to be analysed is how a producer in region *i* can

best spread his annual supplies w_{i0} over the T periods if future prices are uncertain. Before modelling the sequential supply decision process of the producers, I first introduce some factors constraining their supply levels and the random future prices.

Call x_{it} the producer supply in period t in region i. Supplies in period t are constrained by two sales restrictions. First, the producer can not sell more than what remains from previous periods. Introduce for $i = 1,\ldots,n$ and $t = 1,\ldots,T$, the variables w_{it}, which reflect the quantity in stock at the end of period t by the producers in region i. Assume that in each period a fraction $1-\delta$ of the stock is lost, $0 \leq \delta \leq 1$. The stock at the end of period t is $w_{it} = \delta w_{i,t-1} - x_{it}$. Secondly, each producer in region i sells in each period t at least a minimum quantity $\bar{x}_{it}$ to satisfy urgent cash requirements. This implies that $x_{it} \geq \bar{x}_{it}$.
It is assumed that in period $t \in \{1,...,T\}$, prices are known for the periods $1,...,t$. Future prices for the periods $t+1,...,T$ are random variables, the probability distributions of which are assumed to be known. Introduce P_{it}, the random future producer price for period t in region i, for $i = 1,...,n$ and $t = 1,...,T$. For the periods $t = 2,\ldots,T$, I postulate P_{it} as $P_{i,t-1}$, plus a given price increase $\Delta\bar{p}_{it}$, plus a random disturbance Θ_{it}.

$$P_{it} = P_{i,t-1} + \Delta\bar{p}_{it} + \Theta_{it}. \qquad (3)$$

Assume that P_{i1} is given, and has the level $P_{i1} = p_{i1}$. The random variables $\Theta_{i1},\ldots,\Theta_{iT}$ are assumed to be independent variables, with $E\Theta_{it} = 0$. They all have a discrete distribution with K possible realisations, called θ_{it}^k, for $i = 1,\ldots,n$, $t = 2,\ldots,T$, and $k = 1,\ldots,K$. The discrete probability function of Θ_{it} is given by

$$\Pr\left(\Theta_{it} = \theta_{it}^k\right) = f_{it}^k \qquad (4)$$

for $k = 1,\ldots,K$, with probabilities f_{it}^k. For a given level of $P_{i,t-1} = p_{i,t-1}$, the range of possible realisations of P_{it} is specified by (3) and (4). Define p_{it}^k as the possible realisations of the random variable P_{it}, for a given level of $P_{i,t-1} = p_{i,t-1}$, for $i = 1,\ldots,n$, $t = 2,\ldots,T$, and $k = 1,\ldots,K$. It follows from (3) and (4) that the conditional probability distribution function of P_{it}, for a given level of $P_{i,t-1} = p_{i,t-1}$ is,

$$\Pr\left(P_{it} = p_{it}^k \middle| P_{i,t-1} = p_{i,t-1}\right) = \Pr\left(P_{it} = P_{i,t-1} + \Delta\bar{p}_{it} + \theta_{it}^k \middle| P_{i,t-1} = p_{i,t-1}\right) = f_{it}^k \qquad (5)$$

Knowing the factors constraining the producer's supplies and the random future prices, the producer's supply decisions can be modelled. At the beginning of the first period, producers do not make final decisions on the optimal supplies for all periods. For each period, the producer has a different decision problem. In the decision problem for period 1, producers decide on the optimal supplied quantity x_{i1}, based on w_{i0}, the observed price p_{i1}, and the distribution of random future prices $P_{i2},\ldots,P_{iT}$. In the decision problem for period $t \in \{2,...,T\}$, they decide on the optimal supplies x_{it} for that period. These decisions depend on the quantity remaining from the previous period, $\delta w_{i,t-1}$, the observed price p_{it}, and the probability distribution of the random prices $P_{i,t+1},\ldots,P_{iT}$ for the periods t+1 to T.

Consider the producers' decision problem for period t. To choose between selling now or later, the producer balances net revenues from current sales and discounted expected net revenues from selling later. Define σ the discount rate. The discounted expected future net revenues can be interpreted as the present value of expected future net revenues. Net revenues depend on the costs, $c_{it}(x_{it})$, which have been made to produce and sell x_{it}. It will be assumed that the cost function is linear. For $i = 1,\ldots,n$ and $t = 1,\ldots,T$,

$$c_{it}(x_{it}) = c_{it}x_{it}, \qquad (6)$$

with $c_{it} > 0$ a constant. In a period $t \in \{1,\ldots,T\text{-}1\}$, knowing the stock $\delta w_{i,t\text{-}1}$ remaining from the previous period and the observed price p_{it}, a producer optimises his net revenues for that period plus discounted expected net revenues for future periods. In the final period T, only net revenues for that period are optimised. It is assumed that cereals remaining at the end of period T can not be sold next year. Supplies in a certain period should not be less than the minimum sales and not exceed the available stock. Define for $i = 1,\ldots,n$ and $t = 1,\ldots,T$,

$z_{it}^{pr}(w_{i,t-1}, p_{it})$ the optimal current plus discounted expected future net revenues of the producer in region i for period t;

$E\left(z_{i,t+1}^{pr}(w_{it}, P_{i,t+1}) \middle| P_{it} = p_{it}\right)$ the expectation of $z_{i,t+1}^{pr}$ with respect to the random price $P_{i,t+1}$, for a given level of $P_{it} = p_{it}$, i.e. the expectation of the optimal net revenues for period t+1 plus discounted expected future net revenues for the periods t+2 to T.

The sequential decision process can be modelled using a so-called recourse model. The producer's decision problem for period $t \in$

{1,…,*T*} can be formulated as the following maximisation problem in the variables x_{it} and w_{it}.

$$z_{it}^{pr}\left(w_{i,t-1}, p_{it}\right) = Max\left\{\left(p_{it} - c_{it}\right)x_{it} + \sigma E\left(z_{i,t+1}^{pr}\left(w_{it}, P_{i,t+1}\right)\middle| P_{it} = p_{it}\right) \middle| x_{it}^{-} \le x_{it} \le \delta w_{i,t-1}, w_{it} = \delta w_{i,t-1} - x_{it}\right\} \tag{7}$$

Define $x_{i,t+1}^{k}$ the supply level in period t+1 and $w_{i,t+1}^{k}$ the stock level at the end of period t+1 if the producer price is $p_{i,t+1}^{k}$, for k = 1,…,K and i = 1,…,n. In (7),

$$E\left(z_{i,t+1}^{pr}\left(w_{it}, P_{i,t+1}\right)\middle| P_{it} = p_{it}\right) = \sum_{k=1}^{K} f_{i,t+1}^{k} z_{i,t+1}^{pr}\left(w_{it}, p_{i,t+1}^{k}\right) \tag{8}$$

with the decision variables $x_{i,t+1}^{k}$ and $w_{i,t+1}^{k}$ for all k = 1,…,K. It will be assumed that remaining stocks at the end of period T do not yield any future revenues, i.e. $E\left(z_{i,T+1}^{pr}\left(w_{iT}, P_{i,T+1}\right)\middle| P_{iT} = p_{iT}\right) = 0$. The supply problem (7) changes into the following maximisation problem with the decision variables x_{it}, $x_{i,t+1}^{k}$, w_{it}, and $w_{i,t+1}^{k}$, for all k = 1,…,K.

$$\begin{aligned} z_{it}^{pr}\left(w_{i,t-1}, p_{it}\right) = Max\Big\{ & \left(p_{it} - c_{it}\right)x_{it} + \sigma \sum_{k=1}^{K} f_{i,t+1}^{k}\Big[\left(p_{i,t+1}^{k} - c_{i,t+1}\right)x_{i,t+1}^{k} \\ & + \sigma E\left(z_{i,t+2}^{pr}\left(w_{i,t+1}^{k}, P_{i,t+2}\right)\middle| P_{i,t+1} = p_{i,t+1}^{k}\right)\Big] \Big| x_{it}^{-} \le x_{it} \le \delta w_{i,t-1}, w_{it} = \delta w_{i,t-1} - x_{it} \\ & x_{i,t+1}^{-} \le x_{i,t+1}^{k} \le \delta w_{it}, w_{i,t+1}^{k} = \delta w_{it} - x_{i,t+1}^{k}, k = 1,...,K \Big\} \end{aligned} \tag{9}$$

In Ruijs (2002), this model is worked out in more detail. The producer supply model (7) and (9) will be used in Section 0 to set up the stochastic, equilibrium model.

Trader strategies

The traders on the n markets maximise their net revenues. The traders together are called here the aggregate trader. In period t, he purchases a quantity q_{it} from the producers in region i, transports a quantity q_{ijt} between the markets i and j, stores a quantity v_{it} in region i, and sells a quantity r_{it} to the consumers in region i. The quantity stored is defined as:

$$v_{it} = \left(q_{it} + \sum_{\substack{j=1 \\ j \ne i}}^{n} q_{jit} + \delta \cdot v_{i,t-1}\right) - \left(r_{it} + \sum_{\substack{j=1 \\ j \ne i}}^{n} q_{ijt}\right) \tag{10}$$

Suppose that $v_{i0} = 0$ and $v_{iT} = 0$. The purchases and sales of the aggregate trader are constrained by the supplies and demands of the producers and consumers, $q_{it} \leq x_{it}$ and $r_{it} \leq y_{it}$. Transporting one unit of cereals from region i to region j costs him τ_{ijt}, and storing one unit in period t costs him k_{it}. It will be assumed, for simplicity, that transporting from a region i to a region j costs more if transport goes via another region $s \neq i \neq j$: $\tau_{ijt} < \tau_{ist} + \tau_{sjt}$. Furthermore, assume that in period t, the trader knows the prices p_{it} and π_{it}, but that future prices are random variables of which the probability distributions are known. As for the producers, the basic characteristic of the trader's strategy to cope with uncertain prices, and uncertain supply and demand, is the sequential nature of the decision process. The trader's decision problem has many similarities with the producer supply problem discussed above. In period $t \in \{1,...,T\}$, he decides on the optimal strategies for this period, taking into account the strategies which he *expects* to be optimal in future periods. His decisions in period t are based on the observed current market prices, p_{it} and π_{it}, and the probability distribution of possible prices for the future periods $\tau = t+1,\ldots,T$.

Like in the producer problem, it is assumed that traders know the probability distributions of the stochastic future prices, which have a discrete distribution. Introduce, for $i \in \{1,\ldots,n\}$, $t \in \{1,\ldots,T\}$, P_{it} and Π_{it}, the random future producer and consumer price for period t in region i and Φ_t the random disturbance in period t. Furthermore, introduce for $i = 1,\ldots,n$, $t = 2,\ldots,T$, the parameters $\Delta\bar{p}_{it}$ and $\Delta\bar{\pi}_{it}$, which reflect the fixed increase of the producer and consumer price, respectively. Assume for $i = 1,\ldots,n$ and $t = 1,\ldots,T$, like in (3), that random producer prices P_{it} and random consumer prices Π_{it} depend on $P_{i,t-1}$ and $\Pi_{i,t-1}$, a given price increase $\Delta\bar{p}_{it}$ and $\Delta\bar{\pi}_{it}$, and a random disturbance Φ_t. I assume, for simplicity, that the disturbance Φ_t is the same for all regions. Assume that P_{i1} and Π_{i1} are given, and that $P_{i1} = p_{i1}$ and $\Pi_{i1} = \pi_{i1}$. Then, for $i = 1,\ldots,n$, and $t = 2,\ldots,T$,

$$P_{it} = P_{i,t-1} + \Delta\bar{p}_{it} + \Phi_t \qquad (11)$$
$$\Pi_{it} = \Pi_{i,t-1} + \Delta\bar{\pi}_{it} + \Phi_t$$

The random variables $\Phi_1,\ldots,\Phi_T$ are assumed to be mutually independent with $E\Phi_t = 0$. They have a discrete distribution with K possible realisations, defined by ϕ_t^k. The discrete probability distribution function of Φ_t is given by

$$\Pr\left(\Phi_t = \phi_t^k\right) = g_t^k \tag{12}$$

for $k = 1,\ldots,K$, with probabilities g_t^k. For given levels of $P_{i,t-1} = p_{i,t-1}$ and $\Pi_{i,t-1} = \pi_{i,t-1}$, the range of possible realisations of P_{it} and Π_{it} are completely specified by (11) and (12). Define p_{it}^k the possible realisations of P_{it} for a given level of $P_{i,t-1} = p_{i,t-1}$, and π_{it}^k the possible realisations of Π_{it} for a given level of $\Pi_{i,t-1} = \pi_{i,t-1}$, for $i = 1,\ldots,n$, $t = 2,\ldots,T$, and $k = 1,\ldots,K$. It follows from (11) and (12) that, for $t = 2,\ldots,T$, and $k = 1,\ldots,K$, [24]

$$\begin{aligned}
&\Pr\left(\Pi_{it} = \pi_{it}^k, P_{it} = p_{it}^k \middle| \Pi_{i,t-1} = \pi_{i,t-1}, P_{i,t-1} = p_{i,t-1}, i \in \{1,\ldots,n\}\right) = \\
&\Pr\left(\Pi_{it} = \Pi_{i,t-1} + \Delta\bar{\pi}_{it} + \phi_t^k, P_{it} = P_{i,t-1} + \Delta\bar{p}_{it} + \phi_t^k\right. \\
&\qquad \left.\middle| \Pi_{i,t-1} = \pi_{i,t-1}, P_{i,t-1} = p_{i,t-1}, i \in \{1,\ldots,n\}\right) = g_t^k
\end{aligned} \tag{13}$$

In each period $t \in \{1,\ldots,T\}$ the aggregate trader optimises his current revenues for period t, plus the expected future revenues for the periods t+1 to T, depending on the known current producer and consumer prices, p_{it} and π_{it}, the known stock $v_{i,t-1}$, and the stochastic future prices, $P_{i\tau}$ and $\Pi_{i\tau}$. Define for $t \in \{1,\ldots,T\}$, $z_t^{tr}\left(\pi_{it}, p_{it}, v_{i,t-1}\right)$ the optimal current plus expected future revenues of the trader in period t. Like the producer supply problem, the trader's sequential decision process can be modelled using a recourse model. For period t the problem can be written as a maximisation problem in the variables r_{it}, q_{it}, q_{ijt}, and v_{it}, for all $i,j = 1,\ldots,n$, $i \neq j$.

$$\begin{aligned}
z_t^{tr}\left(\pi_{it}, p_{it}, v_{i,t-1}, i \in \{1,\ldots,n\}\right) = Max\Bigg\{ & \left(\sum_{i=1}^{n}\left[(\pi_{it} - \alpha)r_{it} - p_{it}q_{it} - \sum_{\substack{j=1 \\ j\neq i}}^{n}\tau_{ijt}q_{ijt} - k_{it}v_{it}\right]\right) \\
& + \alpha E Z_{t+1}^{tr}\left(\Pi_{i,t+1}, P_{i,t+1}, v_{it}, i \in \{1,\ldots,n\} \middle| \Pi_{it} = \pi_{it}, P_{it} = p_{it}, i \in \{1,\ldots,n\}\right) \\
& \Bigg| q_{it} + \sum_{\substack{j=1 \\ j\neq i}}^{n} q_{jit} + \delta v_{i,t-1} = r_{it} + \sum_{\substack{j=1 \\ j\neq i}}^{n} q_{ijt} + v_{it}; \\
& 0 \leq q_{it} \leq x_{it}; 0 \leq r_{it} \leq y_{it}; q_{ijt}, v_{it} \geq 0, i, j = 1,\ldots,n, j \neq i\Bigg\}
\end{aligned} \tag{14}$$

with α trader's transaction costs, which have to be made for each unit sold. These costs include e.g. taxes and personnel costs. The quantities

[24] (13) is a short notation for $\Pr(\Pi_{1t} = \pi_{1t}^k, P_{1t} = p_{1t}^k, \ldots, \Pi_{nt} = \pi_{nt}^k, P_{nt} = p_{nt}^k \mid \Pi_{1,t-1} = \pi_{1,t-1}, P_{1,t-1} = p_{1,t-1}, \ldots, \Pi_{n,t-1} = \pi_{n,t-1}, P_{n,t-1} = p_{n,t-1})$, for $k \in \{1,\ldots,K\}$.

$v_{i,t-1}$ are the known stocks remaining from the previous period. $EZ^{tr}_{t+1}(\cdot)$ refers to the expectation of $z^{tr}_{t+1}(\cdot)$, with $\pi_{i,t+1}$ and $p_{i,t+1}$ replaced by the random prices $\Pi_{i,t+1}$ and $P_{i,t+1}$. Note that $EZ^{tr}_{T+1}(\cdot) = 0$ Define $q^k_{i\tau}, r^k_{i\tau}, q^k_{ij\tau}$ and $v^k_{i\tau}$ as the purchased, sold, transported and stored quantities, and $x^k_{i\tau}$ and $y^k_{i\tau}$ the upperbounds on the purchases and sales, if producer and consumer prices in period τ and region i are $p^k_{i\tau}$ and $\pi^k_{i\tau}$ for $\tau \in \{t+1,...,T\}$. We can write $EZ^{tr}_{t+1}\left(\Pi_{i,t+1}, P_{i,t+1}, v_{it}, i \in \{1,...,n\} \middle| \Pi_{it} = \pi_{it}, P_{it} = p_{it}, i \in \{1,...,n\}\right) = \sum_{k=1}^{K} g^k_{t+1} \cdot z^{tr}_{t+1}\left(\pi^k_{i,t+1}, p^k_{i,t+1}, v_{it}, i \in \{1,...,n\}\right)$. The trader model may now be written as

$$
\begin{aligned}
z^{tr}_t(\pi_{it}, p_{it}, v_{i,t-1}, i \in \{1,...,n\}) = Max \Bigg\{ & \sum_{i=1}^{n} \left[(\pi_{it} - \alpha) r_{it} - p_{it} q_{it} - \sum_{\substack{j=1 \\ j \neq i}}^{n} \tau_{ijt} q_{ijt} - k_{it} v_{it} \right] + \\
& + \sigma \sum_{k=1}^{K} g^k_{t+1} \cdot \left[\sum_{i=1}^{n} \left[(\pi^k_{i,t+1} - \alpha) r^k_{i,t+1} - p^k_{i,t+1} q^k_{i,t+1} - \sum_{\substack{j=1 \\ j \neq i}}^{n} \tau_{ij,t+1} q^k_{ij,t+1} - k_{i,t+1} v^k_{i,t+1} \right] + \right. \qquad (15) \\
& \left. + \sigma \cdot EZ^{tr}_{t+2}\left(\Pi_{i,t+2}, P_{i,t+2}, v^k_{i,t+1}, i \in \{1,...,n\} \middle| \Pi_{i,t+1} = \pi^k_{i,t+1}, P_{i,t+1} = p^k_{i,t+1}, i \in \{1,...,n\}\right) \right] \\
& q_{it} + \sum_{\substack{j=1 \\ j \neq i}}^{n} q_{jit} + \delta v_{i,t-1} = r_{it} + \sum_{\substack{j=1 \\ j \neq i}}^{n} q_{ijt} + v_{it}; \; 0 \leq q_{it} \leq x_{it}; \; 0 \leq r_{it} \leq y_{it}; \\
& q^k_{i,t+1} + \sum_{\substack{j=1 \\ j \neq i}}^{n} q^k_{ji,t+1} + \delta v_{it} = r^k_{i,t+1} + \sum_{\substack{j=1 \\ j \neq i}}^{n} q^k_{ij,t+1} + v^k_{i,t+1}; 0 \leq q^k_{i,t+1} \leq x^k_{i,t+1}, 0 \leq r^k_{i,t+1} \leq y^k_{i,t+1} \\
& q_{ijt}, v_{it}, q^k_{ij,t+1}, v^k_{i,t+1} \geq 0, \; i, j = 1,...n, j \neq i, k = 1,...,K \Bigg\}
\end{aligned}
$$

Solving the above model gives the optimal trader strategies. Some properties of these strategies are derived in Ruijs (2002). These models and its results are used in the next section to set up the spatial equilibrium model, and to verify whether results of that model are in line with the optimal strategies of the traders.

Spatial equilibrium on *n* markets: a stochastic, multi-period model

In this section a stochastic, multi-period, spatial equilibrium models will be set up. For each period $t = 1,...,T$, a different model will be set up in which optimal strategies for the current period t are determined. In the model for the period t, the optimal values of the following variables are determined for $i = 1,...,n$: producer prices p_{it} and consumer prices π_{it}, producer supply x_{it}, consumer demand y_{it}, total transported quantities x_{ijt} to the various regions, and stock levels s_{it} at

the end of period t. These quantities depend on known stock levels at the end of period t-1, $s_{i,t-1}$, on the available producer stock $w_{i,t-1}$, and on uncertain future prices. In the equilibrium model also future transacted quantities are determined, which are expected to be optimal at the stochastic future prices.

In the stochastic, multi-period, spatial equilibrium model for period t, current semi-welfare for period t plus *expected* future semi-welfare for the periods t+1 to T are optimised. In welfare theory, semi-welfare is defined as the sum of consumer, producer, and trader 'net revenues'. Given some suppositions on supply and demand behaviour this can be written as the, well known, sum of producer and consumer surplus, see e.g. Varian (1992) and Ruijs (2002). Since I adopted different suppositions in the producer supply problem, see above, it is not possible to write producer surplus as the integral of the inverse supply function. The net revenues of the different market actors for period t are

(a) Current consumer net revenues: $\sum_{i=1}^{n}(u_{it}(y_{it})-\pi_{it}y_{it})$, i.e. utility minus costs to purchase y_{it}.

(b) Current producer net revenues: $\sum_{i=1}^{n}(p_{it}-c_{it})x_{it}$, i.e. revenues from sales minus supply costs.

(c) Current trader net revenues: $\sum_{i=1}^{n}\left((\pi_{it}-\alpha)y_{it}-p_{it}x_{it}-\sum_{\substack{j=1\\j\neq i}}^{n}\tau_{ijt}x_{ijt}-k_{it}s_{it}\right)$, see (14).

Due to the properties of integrability of the utility function (see (2)), current semi-welfare (a) + (b) + (c) can be written as:

$$\sum_{i=1}^{n}\left(\int_{0}^{y_{it}}\pi_{it}(\xi)d\xi-c_{it}x_{it}-\sum_{\substack{j=1\\j\neq i}}^{n}\tau_{ijt}x_{ijt}-k_{it}s_{it}-\alpha y_{it}\right) \qquad (16)$$

where the variables, y_{it}, x_{it}, x_{ijt}, and s_{it} have to satisfy the constraint and non-negativity conditions:

$$x_{it}+\sum_{\substack{j=1\\j\neq i}}^{n}x_{jit}+\delta s_{i,t-1}=y_{it}+\sum_{\substack{j=1\\j\neq i}}^{n}x_{ijt}+s_{it} \qquad (17)$$

$$0 \le x_{it} \le \delta w_{i,t\text{-}1},\ y_{it} \ge 0,\ s_{it} \ge 0,\ x_{ijt} \ge 0, \quad i,j = 1, 2, ..., n;\ j \ne i. \qquad (18)$$

for given stocks $s_{i,t\text{-}1}$ and $w_{i,t\text{-}1}$. Assume that $s_{iT} = 0$ and $s_{i0} = 0$.

Expected future semi-welfare for the periods t+1 to T is the sum of expected consumer, and expected producer, and expected trader revenues, with regard to random future producer and consumer prices prices $P_{i\tau}$ and $\Pi_{i\tau}$, for $\tau = t$+1 to T. The perception of probability distributions of future prices may differ between producers, consumers and traders, depending on the information they have. Assume that producers perceive a price probability distribution function which is defined by (5), and that the price probability distribution for the traders is defined as in (13). For consumers in region i, it is assumed that the random future consumer prices Π_{it} and probability distribution are defined as Pr ($\Pi_{it} = \pi^k_{it}$) = h^k_{it}, with π^k_{it} possible price realisations and with probabilities h^k_{it}, for k = 1,...,K. Optimal expected future revenues for the consumers for the the periods t+1 to T, can be defined as:

$$EZ^c_{i,t+1}(\Pi_{i,t+1}) = \sum_{k=1}^{K} h^k_{i,t+1} \cdot \left(u_{i,t+1}(y^k_{i,t+1}) - \pi^k_{i,t+1} y^k_{i,t+1} + \sigma EZ^c_{i,t+2}(\Pi_{i,t+2})\right)$$

in which $y^k_{i\tau} = y_{i\tau}(\pi^k_{i\tau})$, the demand in period τ, $\tau = t$+1,...,T, if the consumer price is π^k_{it}, for k = 1,...,K. These revenues are a constant, since all elements are constants. Define $EZ^c_{i,T+1}(.) = 0$. Expected future producer and trader revenues have already been discussed in Section 0, see (8), (9) and (15).

Define for each period $t \in \{1,\ldots,T\}$, $z_t(s_{i,t\text{-}1}, w_{i,t\text{-}1})$ the optimal current plus expected future semi-welfare, knowing the producer and trader stocks available at the beginning of period t, $w_{i,t\text{-}1}$ and $s_{i,t\text{-}1}$. Optimising the sum of current semi-welfare for period t plus expected future semi-welfare, subject to the market equilibrium condition (17) for period t and the supply upperbound $x_{it} \le \delta w_{i,t\text{-}1}$, results in the following stochastic, multi-period, spatial equilibrium model for period $t \in \{1,...,T\text{-}1\}$:

$$z_t(s_{i,t-1}, w_{i,t-1}) = Max\left\{\sum_{i=1}^{n}\left[\int_0^{y_{it}} \pi_{it}(\xi)d\xi - c_{it}x_{it} - \sum_{\substack{j=1\\ j\neq i}}^{n}\tau_{ijt}x_{ijt} - k_{it}s_{it} - \alpha y_{it}\right] + \right.$$

$$\sigma\sum_{i=1}^{n} EZ^{c}_{i,t+1}(\Pi_{i,t+1}) + \sigma\sum_{i=1}^{n} E\left(Z^{pr}_{i,t+1}(w_{it}, P_{i,t+1}) \middle| P_{it} = \hat{p}_{it}\right)$$

$$+\sigma E\left(Z^{tr}_{t+1}(\Pi_{i,t+1}, P_{i,t+1}, s_{it}, i \in \{1,...,n\}) \middle| \Pi_{it} = \hat{\pi}_{it}, P_{it} = \hat{p}_{it}, i \in \{1,...,n\}\right) \quad (19)$$

$$\left| x_{it} + \sum_{\substack{j=1\\ j\neq i}}^{n} x_{jit} + \delta s_{i,t-1} = y_{it} + \sum_{\substack{j=1\\ j\neq i}}^{n} x_{ijt} + s_{it}; x^{-}_{it} \leq x_{it} \leq \delta w_{i,t-1} \right.$$

$$\left. w_{it} = \delta w_{i,t-1} - x_{it}; y_{it}, x_{ijt}, s_{it} \geq 0,\ i, j = 1,...,n, j \neq i \right\}$$

The model for period T is similar to (19), but with $s_{iT} = 0$, and without the terms for the expected future revenues.

From the Lagrangian and the Kuhn-Tucker conditions, it is possible to prove that the optimal equilibrium producer price is equal to the Lagrange multiplier (or shadow price) of equilibrium constraint (17) of the equilibrium model. At this price, it is optimal for the producers to supply the equilibrium supplied quantity x_{it}. Furthermore, at the equilibrium prices, the optimal supplied, demanded, transported and stored quantities resulting from model (19) (x_{it}, y_{it}, x_{ijt}, s_{it}) are equal to the optimal purchases, sales, transport flows, and stock levels of the traders (q_{it}, r_{it}, q_{ijt}, v_{it}) (see Ruijs, 2002). Moreover, it can be proved that if in a certain period goods are purchased and sold in one region, or purchased in one and sold in another region, then the difference between consumer and producer prices is equal to the marketing costs (transaction and transport costs: $\pi_{it} = p_{it} + \alpha_{it}$ and $\pi_{jt} = p_{it} + \tau_{ijt} + \alpha_{jt}$). To conclude, the future price uncertainty has an influence on the current price levels. The results of the model will be such that a trader will store if this is expected to be profitable.

Parameter estimates

In this section, it is discussed how the parameters used in model (19) are estimated. Estimation of these elements is based on a careful review of existing literature on cereal trade, production, and consumption in Burkina Faso.[25] For a detailed discussion of the

[25] The data used and surveys consulted include data from the Ministère de l'Agriculture et de l'Elevage (1984-1999) and from INSD (1995a,b, 1996a,b, 1998); surveys from the Universities of Michigan and Wisconsin, in particular Saul (1986, 1987), McCorkle (1987), Pardy (1987), Sherman et al. (1987), Szarleta (1987), and Ellsworth and Shapiro (1989); surveys by ICRISAT, in particular Lang et al. (1983), Lang (1985), Reardon et al. (1987, 1988a,b, 1989, 1992); and surveys by Broekhuyse (1983, 1988, 1998), Roth (1986), Thiombiano et al. (1988), Pieroni

parameter estimates, I refer to Ruijs (2002). The exogenous elements of the equilibrium model are the cereal supply and demand functions, the storage costs and losses per stored kg per unit of time, and the transport costs per transported unit of weight between the various markets.

For the analysis a planning period of one year is considered. The planning year is divided in four periods of three months each, starting with the harvest period from October to December (see Figure 2 in the appendix). The regions distinguished in this study are the 12 Burkinabé administrative regions (the CRPA: Centre Regional de Promotion Agricole), see Figure 1 in the appendix. It is assumed that cereal harvest levels are known at the beginning of the planning year. For each period and each region aggregate producer supply and consumer demand functions will be estimated for the *reference year* October 2000 to September 2001.

The estimation of the model parameters for the reference year is based on the following information. 1) The size of the rural and urban population in the reference year, see Table 1; 2) Forecasted mean production levels per person in the reference year, see Table 1; 3) Sales and 4) purchase patterns in different regions, which have been discussed in several surveys performed in the past in Burkina Faso; 5) Rural and urban household revenues and expenses, which have been analysed by INSD (1996a,b), to estimate sales income and purchasing capacity; 6) Seasonal price patterns, see Table 2; and 7) Marketing costs. For the marketing costs, I make a distinction between transport costs, storage costs, and transaction costs. Transaction costs include among other things costs to purchase bags, market taxes, and personnel costs. To estimate transport costs between the main cities in each CRPA, I used surveys executed by Sirpé (2000), Bassolet (2000) and Déjou (1987) – see Table 3 in the appendix. Storage and transaction costs are estimated on the basis of surveys by Bassolet (2000), Sherman et al. (1987) and Déjou (1987). Storage costs include renting costs, surveillance costs and also capital costs, which account for the forgone revenues if a trader had invested his capital in other activities instead of storing cereals. Storage costs are estimated at 300 FCFA per bag of 100 kg, capital costs per period are estimated at 3.5% of the producer price given in Table 2. Storage losses for traders are observed to be higher than for farmers: 12% per year. Transaction costs include costs for bags, market taxes and personnel costs, and are estimated at

(1990), Maatman et al. (1996), Yonli (1997), Maatman (2000), Bassolet (2000), and Sirpé (2000).

1500 FCFA per 100 kg bag of cereals. Finally, the discount rate is estimated at 0.97 per period.

Using the data mentioned above, cereal demand functions can be estimated as a function of cereal prices. The cereal demand functions per period and per CRPA opted for in this paper are derived from the widely applied Linear Expenditure System (LES) (see e.g Roth (1986) for a discussion and application of the LES). The LES demand function assumes that for each good, demand in each period consists of a minimum required quantity and a part which depends on income and consumer price. A difference must be made between the demand function of a rural and of an urban household. Define the set of time periods (see also Figure 2): $T = \{t_1, t_2, t_3, t_4\}$, the set of twelve CRPA J, and the set of household types $H = \{urban, rural\}$. Introduce for each period $t \in T$, each CRPA $j \in J$ and each household of type $h \in H$: the cereal demand level of a consumer, y^h_{jt}; the minimally required cereal purchase level of a consumer, γ^h_{jt}; the cereal consumer price in period t, π_{jt}; minimally required expenses on all other commodities but cereals, ξ^h_{jt}; and the income level of a consumer, m^h_{jt}.. m^h_{jt} - ξ^h_{jt} can be interpreted as the supernumerary income level of a consumer which remains after due allowance for the minimum requirements of all commodities but cereals. We define the share of supernumerary income spent on cereals, b^h_{jt}. The quarterly demand functions for *urban* and *rural* consumers are defined as:

$$y^h_{jt} = \gamma^h_{jt} + \frac{b^h_{jt}}{\pi_{jt}}\left(m^h_{jt} - \xi^h_{jt} - \pi_{jt}\gamma^h_{jt}\right) \qquad (20)$$

The estimates of the parameters of the demand function are based on both quantitative and qualitative evidence presented in the sources discussed in above. In Ruijs (2002) it is discussed in detail how they are estimated. It is assumed for the minimally required purchase levels for rural households that $\gamma^r_{jt} = 0$. They take a subtantial part of their consumption from their own production and do not have to purchase a minimum quantity of cereals. For rural households, it is supposed that a large part of their food consumption consists of rice and other non-cereal commodities. It is assumed that in each period $\gamma^\mu_{jt} = 50$ kg for urban consumers in Ouagadougou and Bobo-Dioulasso, and $\gamma^\mu_{jt} = 60$ kg for other cities. Average income levels per period per consumer, m^h_{jt}, the supernumerary income levels m^h_{jt} - ξ^h_{jt}, and the share of supernumerary income spent on cereals, b^h_{jt}, are mainly based on INSD

(1996a,b) and Roth (1986). The estimates are discussed in detail in Ruijs (2002).

Producer supply behaviour has been discussed in Section 3.1. The parameters used for this analysis are the annual supply w_{i0}, minimally required supply per period $\bar{x}_{it}$ supply costs c_{it}, storage losses δ, and discount rate σ. In Ruijs (2002) these estimates are discussed in detail.

4. Effects of Institutional Improvements on Cereal Trade

In this section, the model discussed in the previous section will be used to analyse the effects of the three scenarios of institutional improvements formulated in Section 2. First, the results of the model with the parameter values as discussed in the previous section will briefly be discussed. This model is called the base model. These results serve as a benchmark with which the results of the scenario analysis will be compared. Next, for each of the three scenarios, some of the parameter values or model equations are adapted in order to analyse their effect on cereal trade.

Base model

The results of the base model reflect actual prices and trade flows on the cereal market in Burkina Faso fairly well (see Table 4 in the appendix). They show that optimal equilibrium prices are highest in the shortage areas Centre, Sahel, Nord, and Centre Nord, and lowest in the surplus areas Mouhoun, Hauts Bassins, and Sud Ouest (see Figure 1 in the appendix). The optimal equilibrium prices reflect the costs which are made by the traders and seasonality well. Prices increase gradually during the year, due to storage costs and the forces of supply and demand.

In some of the regions (Comoé and Sahel), the producers only sell the minimally required quantity of cereals, because they expect to earn more if they sell in the next periods or because selling is unprofitable for them. In some regions the largest quantity is sold during the post-harvest season, but in most regions producers supply their largest quantity later in the year when prices are higher. This does not correspond with the common view that farmers in developing countries sell when prices are low and purchase when prices are high. It corresponds, however, with observations by Sherman et al. (1987), who conclude that, although the number of selling households is largest during the post-harvest season, the sales per selling household are lower during the post-harvest season than during the seasons later

in the year. This indicates that households which do not have to sell cheap, prefer to wait until prices increase. This result also corresponds to observations by Armah (1989) for Ghana, Lutz (1994) for Benin, and Bassolet (2000) for Burkina Faso, that most goods are stored by the producers and that only a few traders store for a longer period. Note that the results only show aggregate supplies. If more classes of producers were distinguished in the analysis, it is well possible that the results would show that poor farmers have a different supply pattern.

In the optimal solution, traders transport the surpluses from the surplus regions to the shortage regions. About 41% of the marketable surplus is transported to other regions. Especially transport from the largest surplus zones Mouhoun and Hauts Bassins towards the shortage regions Centre, Sahel, Nord, and Centre Nord are important. The transported quantities are high especially during the lean season, from July to September, when the farmers' stocks get depleted. Traders only store a small part of the total quantity transacted (4%). No data are available to verify this percentage. The general picture, however, corresponds to observations mentioned above that only a few wholesalers invest in long-term storage, because farmers have a comparative advantage for storage.

Improved infrastructure

The first scenario deals with the influence of road and communication infrastructure on cereal trade. If the quality of infrastructure improves, transport costs will decline which may stimulate more traders to transport to remote areas. The model results show that if transport costs decline, transport is stimulated indeed. However, the direct effect on the quantity transported is small if only transport costs between the main cities in the different regions decrease. It is considerably less than the effect attributed to transport costs by a number of Worldbank studies. For example, in Worldbank (2000), it is argued that a drop of transport costs of 10% will increase trade by 25%. The model results, however, show that if overall transport costs decrease with 25%, transport flows increase only with 0.8%. Also prices hardly change. The price change ranges between –1.7% in the shortage region Sahel to +2.4% in the surplus region Mouhoun. In most regions, equilibrium prices change between –1% and +1%. The effect of transport costs on prices is weak, because the transport costs for the main routes only make up a small part of prices. Due to the forces of supply and demand, prices in the importing regions fall, but the prices in the exporting regions rise. The price decrease in the importing regions can only be modest because of the inelasticity of supply. If the fall of consumer prices would be larger, demand would increase. This can,

however, not be satisfied because supply hardly reacts on small price changes. As a result, prices in the importing regions decrease with a small percentage, prices in the exporting regions increase with a larger percentage, and transport flows increase only a little bit. Due to the fall in production costs, overall welfare increases a bit. However, in the regions in which prices fall (especially the regions which import cereals from other regions), consumers will profit and producers will lose. In the regions in which prices increase (especially the surplus regions), it is the reverse.

If only specific routes are asphalted, transport costs between the regions connected by the new road may decline considerably. For example, by asphalting the road from Dédougou to Dori (see Figure 1), transport costs from Mouhoun to Sahel will drop by 30%. In that case, transport to and from remote regions may show some unexpected changes. Optimal equilibrium prices in the shortage regions along the newly asphalted roads will decline, and quantities transported over these roads will rise, although the effects are small. However, traders will transport less to the other shortage regions, where prices will rise. This has negative consequences for the consumers and retailers in these regions. For example, by asphalting the above mentioned route, equilibrium prices in the shortage region Sahel decrease by 3.9%, and transport to the region Sahel increase with 7.6%. Prices in the region Centre, however, increase with 0.5% and transport to Centre and Centre Nord will fall. More important, however, transporting from the regions which are not along the new road becomes relatively more expensive. As a result, the optimal solution shows that some of the surplus regions in the rest of the country may lose their competitive position. Wholesalers will be more inclined to purchase in the regions from which transport is cheaper. Especially producers and assemblers in the remote surplus regions may notice this effect. For example, if the road from Bobo-Dioulasso via Dédougou to Ouahigouya is asphalted, the producers in the surplus region Comoé supply less than in the base scenario. Cereals transported to Hauts Bassins, which came from Comoé in the base scenario, now originate from Mouhoun. Consumption levels can increase if producers in Comoé supply more. However, the extra utility obtained from a higher consumption, does, apparently, not outweigh the extra transport costs if more is transported. This aspect may even be stronger if also spin off effects of improvements of infrastructure are considered. If economic activity increases in the regions connected by the new road, demand in these regions may increase at the expense of the consumers in other regions.

The impact of improvements in infrastructure will be more pronounced if also transaction costs are affected. Due to better

infrastructure (especially rural roads, telephone and fax lines), assemblers can more cheaply purchase and sell in remote regions and wholesalers can hire non-relatives with less risk of breach as they can monitor their agents more easily. If transport and transaction costs decrease with 25%, the model results show that producers, consumers, and traders will benefit from these changes. Consumer utility will increase for almost all consumers and revenues will increase for almost all producers. Traders can offer higher prices to the producers, demand lower prices from the consumers, and transact larger quantities (+4.7%). Compared with the base results, the consumer prices decrease on average by 1.2% and the producer prices increase by 2.4%. The decrease of consumer prices is highest in the shortage regions, whereas the increase of producer prices is highest in the main surplus regions. Compared with the scenario in which only transport costs fall by 25%, the situation is better now for almost all market actors. Those who are worse off, only see their situation deteriorate by a small percentage. The result that infrastructure has a considerable influence on the situation of the rural population is supported by Fan et al. (2000). They conclude for the case of India, that poverty is reduced substantially if the government invests more in rural roads. Also the Worldbank (1994) concludes that infrastructural improvements (which not only include roads but also electricity, telecommunication, ports, and sewerage) have a considerable effect on GDP.

More accurate price expectations

In the second scenario, the role of information with respect to future price developments in cereal trade is examined. Having adequate future price expectations is important to make trade decisions. However, it is difficult for cereal traders and producers in Burkina Faso to make good price expectations because of the difficulty to obtain correct and up-to-date information on market developments. Having access to better price and market information and knowing how to interpret this information, may result in more adequate price expectations. For this scenario the stochastic equilibrium model is compared with a model in which producers and traders are in a hypothetical situation where they have perfect foresight with regard to future market prices (the so-called perfect market model).

The results of this analysis show that having better price expectations is important. If better information is available, price developments over the year will be smoother. The model results show that the total price increase within a year may not change a lot if the market functions perfectly, but the price changes between the different periods are more equal in the perfect market model than in the base scenario. If price

expectations are better, producers can better spread their supplies, which results in a smoother price development and less drastic changes in the last period. Also traders may operate more efficiently. Transport to surplus regions that also export abates, and storage is done by the producers, who can store at lower costs than traders. These changes are detrimental for transport agencies who see their markets decrease or traders who have invested a lot of time and effort in setting up private trade and information networks. Organisations aiming at improving public market information systems have to be aware of the possibility that traders do not want to share their information or provide wrong information to thwart the plans.

The importance of correct market information becomes even more clear if the situation is considered in which traders and producers have wrong expectations. Consider a situation in which cereal production is 10% lower than expected but in which traders and producers do not adapt their price expectations for the future periods. In that case, producer prices in the first three periods only change a little bit. However, prices in the last period increase suddenly with 45.5% compared to the base scenario. If producers and traders adapt their expectations and expect prices to be 10% higher than in the base scenario, the price increase in the last period will only be 25.7%. So, if they do not know about the change in supply, they may sell too much during the first periods, which then leads to an immense shortage at the end of the year and prices rocketing up in the lean season.

Improved credit facilities

In the third scenario the accessibility of credit is analysed. Credit is generally considered to be one of the main constraining factors of cereal trade. A lack of credit opportunities would prevent small traders from extending their businesses and prevent employees of wholesalers to start their own cereal trade business. If credit is more easily accessible, the need for setting up extensive trade networks with pre-financed agents will be less an issue. In that case, it is expected that trade between individual traders will augment, and competition will increase. In this case, several types of traders have been distinguished in the model, each with different marketing costs. Furthermore, two different situations are distinguished. In situation A, an unlimited amount of capital can be borrowed. In situation B, each trader can only borrow a limited amount of capital. It is assumed that the banks lend only 75% of the money that has been borrowed by the traders in situation A. In fact, in situation A credit facilities function perfectly.

The results of the analyses clearly show that the level of competition rises if the availability of capital improves, indeed. If not enough

capital is available to finance new entrants on the market, traders can make excessive profits. They may offer low producer prices and demand high consumer prices. Due to the lack of capital, no traders can enter the market to offer higher prices to the producers and in this way attract all supplies. Due to the low producer price, supply will be low (-8% compared to situation A), resulting in high consumer prices. In situation B, in the periods April – June and July – September, consumer prices are respectively 13% and 48% higher whereas the producer prices are 7% lower than in situation A. In situation A, the situation is better for all producers and consumers. Also the transport companies will benefit from the better availability of capital, as this will result in a higher demand for transport services (transport flows increase with 11%). On the other hand, the traders which do have capital will be better of in situation A than in situation B.

Furthermore, the analysis also shows that in the case of a restricted availability of capital, transport and storage are not necessarily done by the most efficient trader. If capital is not constraining, each trader makes the transactions for which he has the lowest costs. The traders who have a comparative advantage for a certain activity will perform this activity, because they can offer or demand the best prices. The others will be priced out of the market. For example, consider a situation with two types of traders. Transaction costs for traders of type 1 are equal to 15 FCFA/kg whereas those for type 2 are 25% lower (11.25 FCFA/kg). In situation A, in which capital is not constraining, the difference between consumer and producer prices is 11.25 FCFA per kg. This is equal to the transaction costs of the traders of type 2. Since the transaction costs for the other traders are equal to 15 FCFA per kg, they will not purchase and sell any cereals. In Case B, in which capital is constraining, the difference between the consumer and producer price in the regions in which only traders of type 2 operate, is a little less than 15 FCFA/kg in the period October – March. This difference is equal to 15 FCFA/kg in the other regions. Because of the capital constraint, the traders of type 2 do not have to fear the entry of new traders of type 2. Therefore, they can demand consumer prices which exceed the producer prices with more than their transaction costs. On the other hand, they will not ask a price which is more than 15 FCFA/kg higher than the producers price, because this would give the other traders the opportunity to profitably take over a part of their trade. So, in this case, traders can abuse their market power to ask too high prices. To conclude, if credit is more easily accessible, more cereals will be supplied, consumed, transacted, and transported, and prices will be fairer. Especially the remote regions will profit from the improved level of competition.

Conclusions

The results of the stochastic equilibrium model set up in this paper, clearly reveal the effects of some important institutional deficiencies on the cereal market in Burkina Faso. For example, taking into account the uncertainty of future prices has shown how wrong information may result in large shortages and unnecessary price fluctuations; analysing the role of credit has shown that competition is at stake if capital is constraining; inefficiencies by traders may not only result in a loss of capital, but also affect the competitive position of producers in remote regions. Furthermore, an important result of the model is that some claims on the effects of market changes, which have become widely accepted, need some critical reflection. For example, improving infrastructure in one region may unintentionally aggravate the situation of the poor in other parts of the country.

One of the contributions of the model presented here is that it also shows the nuances of how institutional changes may affect cereal prices and cereal distribution and how they may affect the relationships between the market agents. For individual producers or traders, not the overall effects of institutional changes are important, but the way how they are affected individually. Market agents who are affected negatively by institutional developments may frustrate or even block these developments. The evolution of market developments may be governed more efficiently if potential problems are known and tackled beforehand.

Without the use of the equilibrium model and especially the insights it provides about the interaction between the market agents, it would be difficult to explain convincingly some of the results. Adverse effects of seemingly positive market changes, like improvements in road infrastructure, are easily overlooked if cereal trade is analysed in a more general way. The influence of specific costs or behavioural constraints on market prices and quantities traded, can not be entirely understood if they are not studied in an integrated analysis of the behaviour of all producers, consumers, and traders on the cereal market. On the basis of a qualitative study alone, the functioning of the cereal market can not be fully explained. By interviewing market agents, one does not learn exactly how the market works. They may know their own strategies and problems, but they do not know exactly how interactions between agents or certain developments on the market affect prices and transactions in other regions of the country. Only by using an instrument with which the interaction between the market agents can be represented, the complex nature of cereal trade can be explored in an integrated way.

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Appendix

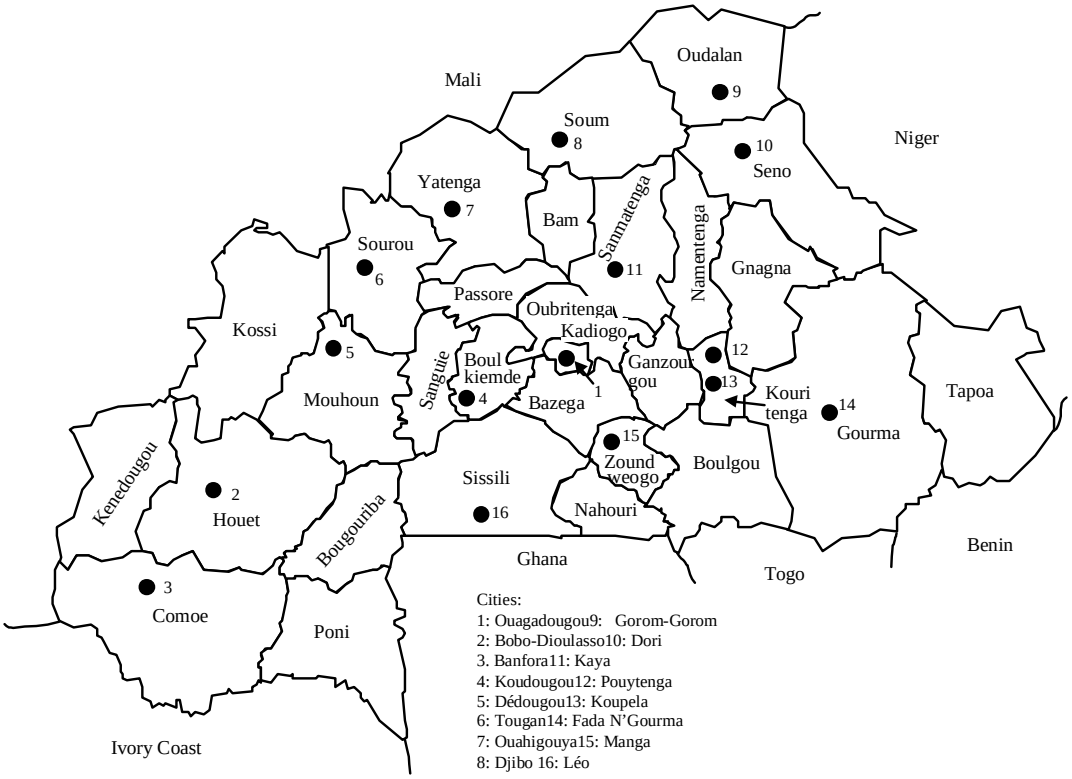

Figure 1: Map of Burkina Faso, the main cities, and the 12 agricultural regions (CRPAs)

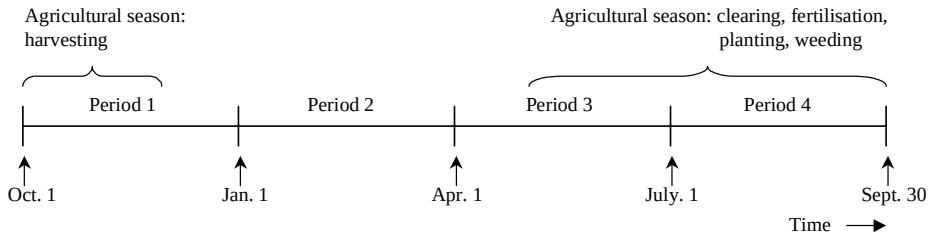

Figure 2: Schematic representation of the planning year

Table 1 **Forecasted population size and forecasted mean cereal production per capita for the total and for the rural population for the reference year 2000-2001.**

	Forecasted urban population 2000 (a)	Forecasted rural population 2000 (b)	Forecasted total population 2000 (c)	Forecasted mean production 2000 (tonnes) (d)	Production (d) –15% loss (tonnes) (e)	Production (e) per rural inhabitant (kg) (f)	Production (e) per person (kg) (g)
Centre	843,454	943,721	1,787,175	144,926	123,187	131	69
Centre Nord	66,820	949,473	1,016,292	183,210	155,728	164	153
Centre Ouest	118,377	942,512	1,060,889	225,630	191,786	203	181
Centre Sud	18,343	50,0577	518,920	160,008	136,006	272	262
Sahel	31,499	761,390	792,889	134,257	114,118	150	144
Mouhoun	101,918	1,140,022	1,241,941	379,850	322,873	283	260
Est	55,799	993,518	1,049,317	251,481	213,759	215	204
Centre Est	103,372	732,877	836,249	156,614	133,122	182	159
Nord	104,111	935,708	1,039,819	154,775	131,559	141	127
Sud Ouest	19,221	524,068	543,289	168,071	142,860	273	263
Hauts Bassins	371,416	737,849	1,109,265	246,802	209,782	284	189
Comoe	76,996	282,655	359,652	87,671	74,520	264	207
Burkina Faso	1,911,328	9,444,371	11,355,699	2,293,294	1,949,300	206	172

Notes: (c) = (a) + (b); (e) = 0.85(d); (f) = (e)/(b); (g) = (e)/(c). Based on census data by INSD and production data by the Minstry of Agriculture; see Ruijs (2002).*

Table 2 **Average national seasonal prices for the period Oct '96 – Sept '99 in FCFA per kg.**

Oct '96 – Sept '99	Producer Cereal price				Year Average	Consumer Cereal price				Year average
	Jan-Mar	Apr-Jun	Jul-Sept	Oct-Dec		Jan-Mar	Apr-Jun	Jul-Sept	Oct-Dec	
Centre						128	136	140	133	134
Centre Nord	104	104	116	100	103	120	129	137	119	126
Centre Ouest	115	125	125	102	115	121	131	134	114	125
Centre Sud	122	131	133	116	123	126	139	126	122	128
Sahel	105	103	93	96	100	133	144	149	131	139
Mouhoun	89	101	103	83	94	103	114	120	96	108
Est	106	113	116	102	109	112	125	133	108	120
Centre Est	111	118	126	117	117	125	132	133	119	127
Nord[1)]				99	111	114	124	128	110	119
Sud Ouest[1)]	83				83	134	143	152	129	139
Hauts Bassins	86	89	95	86	89	108	117	118	108	113
Comoe	105	116	114	122	113	119	134	140	123	129
Burkina Faso	103	109	110	99	104	119	129	133	116	125

Note: 1) Not enough data were available for these CRPA to estimate the average prices for all periods. Source: Data from SIM/SONAGESS

Table 3 :Estimation of the transport costs (in FCFA/100kg bag).

Dry Season	Centre	Centre Nord	Centre Ouest	Centre Sud	Sahel	Mou-houn	Est	Centre Est	Nord	Sud Ouest	Hauts Bassins	Comoé
Centre	0	343	510	377	1097	987	788	274	634	1288	712	1544
Cen. Nord	343	0	925	720	810	1363	1134	826	966	1631	1589	1887
Cen. Ouest	510	925	0	916	1679	990	1370	1062	1130	905	1081	1594
Cen. Sud	377	720	916	0	1474	1364	891	583	886	1839	1623	1921
Sahel	1097	810	1679	982	0	1740	1554	1459	1124	2385	2343	2640
Mouhoun	987	1363	990	1364	1740	0	1775	1467	715	1968	1140	1438
Est	788	1134	1370	891	1554	1775	0	308	1421	2076	2034	2331
Cen. Est	274	826	1062	583	1459	1467	308	0	1113	1768	1726	2023
Nord	634	966	1130	886	1124	715	1421	1113	0	1922	1855	2153
Sud Ouest	1288	1631	905	1839	2385	1968	2076	1768	1922	0	828	1126
Hauts Bass	712	1589	1081	1623	2343	1140	2034	1726	1855	828	0	298
Comoé	1544	1887	1594	1921	2640	1438	2331	2023	2153	1126	298	0

Note: Based on Déjou (1987), Bassolet (2000), and Sirpé (2000).

Table 4 :Results of the base model: Consumer price levels and supply and demand per person

→ PERIOD ↓ CRPA	Consumer price level (FCFA/kg)[1] Oct-Dec	Jan-Mar	Apr-Jun	Jul-Sept	Ave-rage	Supply per producer (kg)[2]	Consumption per rural consumer (kg)	Consumption per urban consumer (kg)[4]
Centre	110	113	119	128	118	23	123	115
Centre Nord	112	115	123	132	120	13	165	101
Centre Ouest	104	107	112	129	113	36	181	104
Centre Sud	105	107	118	122	113	47	238	104
Sahel	113	121	127	140	125	12	163	99
Mouhoun	98	104	108	115	106	82	221	107
Est	104	103	110	121	109	38	197	106
Centre Est	109	108	115	124	114	32	164	104
Nord	107	111	117	126	115	11	145	103
Sud Ouest	99	98	105	116	104	80	211	108
Hauts Bassins	101	109	115	131	114	84	220	118
Comoé	106	104	118	126	113	65	217	104
Average price	106	108	115	126	114		180	106
Total supply (1000 tonnes)[3]	88.3	88.1	90.4	117.9	385			

Quantity transported (in 1000 tonnes)						
From	**To**	**Total**		**From**	**To**	**Total**
Cen. Ouest	**Centre**	12.1		**Est**	**Centre Est**	5.1
Centre Sud	**Centre**	8.1		**Centre Est**	**Centre**	6.5
Centre Sud	**Cen. Nord**	5.8		**Sud Ouest**	**Centre**	13.7
Mouhoun	**Centre**	21.0		**Sud Ouest**	**Cen. Nord**	2.2
Mouhoun	**Cen. Ouest**	5.1		**Sud Ouest**	**Hauts Bass.**	11.9
Mouhoun	**Sahel**	11.9		**Sud Ouest**	**Comoé**	0.8
Mouhoun	**Nord**	14.4		**Hauts Bass.**	**Centre**	23.3
Mouhoun	**Hauts Bass.**	3.4		**Hauts Bass.**	**Comoé**	0.4
Est	**Centre**	5.0		**Comoé**	**Hauts Bass.**	5.8
Est	**Sahel**	1.0		**Total**		157.5

Quantity stored (in 1000 tonnes)	
Cen. Ouest	2.9
Cen. Sud	2.3
Mouhoun	7.4
Est	1.4
Sud Ouest	2.9
Total	17

Notes: 1) The producer price is equal to the consumer price minus 15 FCFA; 2) Total supplies per inhabitant are not equal to the annually available quantity, w_{i0}, because of storage losses;
3) Total supply is the sum over all regions of supply per person multiplied with the rural population per region; 4) Recall that urban consumers are assumed to consume about 80 kg of rice.