unicef

INTERNATIONAL CHILD DEVELOPMENT CENTRE

Innocenti Occasional Papers

Spedale degli Innocenti
Florence, Italy

INNOCENTI OCCASIONAL PAPERS
ECONOMIC POLICY SERIES, NUMBER 38

SPECIAL SUBSERIES
STRUCTURAL ADJUSTMENT IN SUB-SAHARAN AFRICA

POLICY AND CAPITAL MARKET CONSTRAINTS TO THE AFRICAN GREEN REVOLUTION: A STUDY OF MAIZE AND SORGHUM YIELDS IN KENYA, MALAWI AND ZIMBABWE, 1960-91

Paul Mosley*

EPS 38

December 1993

This paper is part of the background documentation for a study on 'From Adjustment and Development in Africa: Conflict, Controversy, Convergence, Consensus?', edited by Giovanni Andrea Cornia and Gerald K. Helleiner and forthcoming in 1994, Macmillan.
* Department of Economics, University of Reading, England.

The author wishes to thank Nikos Alexandratos, Lawrence Smith and Colin Thirtle for their most valuable ideas and suggestions.

CONTENTS

TABLES

FIGURES

I. THE PROBLEM

As is well known, one element in the continuing under-development of sub-Saharan Africa *vis à vis* other parts of the third world is the continuing poor performance of her agricultural, and in particular her food-crop sector. Both in *per capita* and per acre terms, food-crop yields in Africa lag well below performance elsewhere, and in *per capita* terms, food production at the beginning of the 1990s is actually less than it was ten years ago[1]. There can be few more urgent development priorities, whether in terms of relieving pressure on the balance of payments, releasing resources from the food-producing to the tradables sector, or promoting equity by raising the incomes of poor rural people, than finding a means of correcting this dismal performance. Most assessments of the possibility of a green revolution in Africa, however, have been profoundly sceptical, usually for some combination of the following reasons.

1. There does not exist a 'shelf' of high-yielding varieties of African crops that holds out the hope of increasing yields on anything like the same scale as was achieved in Asia in the sixties and seventies through the introduction of modern varieties of wheat and rice[2];

---

1 The data are:

	Food-crop yields 1989-91 as a percentage of 1979/81	
	Per head	Per hectare
Sub-Saharan Africa	95	108
Asia	118	128
Latin America and the Caribbean	105	116
Developing countries total	112	121

Source: World Bank (1991), table 4.

2 Lipton (1988), for example, argues that:

> 'most of Sub-Saharan Africa offers smallholders no dramatic, immediately applicable new technology that might, with plausible increases in output/input price ratios, or in person/land ratios, safely and substantially increase the profitability of food farming over large areas'.

2. Because population densities are lower in Africa than in Asia, the *incentive* to intensify production methods is less, except in a few areas of high population concentration[3];

3. Soil, climate and irrigation potential are all much more hostile to the introduction of modern varieties in Africa than Asia.

The first two of these arguments at least, however, are inadequate. A first indication of the range of available technologies in food-crops has been given by Collinson (1989)[4]; in Table 1, we expand on this by providing a comparison between national average yields and those achieved in on-farm trials, both in dry and in rain-sufficient areas, for the three countries on which we shall wish to focus later in this paper.

---

3 Biswanger and Pingali articulate the conventional wisdom when they argue that:

> 'green revolution techniques that have succeeded in the densely populated regions of Asia are unlikely to be adopted by farmers in large parts of Africa, where land is still abundant and market access poor. No matter how good research and extension is in such places, farmers will not be interested in fertilisers, irrigation, fertiliser-responsive seeds, elaborate crop husbandry, or land improvement and conservation. In such conditions, asking research and extension workers to propagate high yields is a recipe for demoralising them. Instead, farmers are more likely to be attracted by stress-avoiding technologies, new crops, and higher-quality varieties.' (1989, pp. 59-60).

4 Collinson gives the following table, which covers three of the countries to be examined in detail in what follows:

CURRENT AVERAGE YIELDS 1988-90						
Product	Acreage 1989 SSA '000 ha	Nigeria	Kenya	Malawi	Zimbabwe	'High Commercial Expectation'
Sorghum	17,978	935	1,005	(601)	658	5,000
Maize	21,781	1,271	1,715	1,121	1,694	3,500-8,500
Wheat	8,630	2,200	1,770	-	(1,900)	6,000
Cassava	8,904	4,900	7,900	(3,100)	-	25,000
Sweet Potato	1,208	6,500	8,800	7,100	7,600	15,000
Pulses	11,952	650	436	950	1,000	2,000

For data points marked (), the crop in question is not significant in the country named.

Source: Collinson (1989) for 'commercial expectation'; FAO (1991) for other data.

Table 1: KENYA, ZIMBABWE AND MALAWI: MAIZE AND SORGHUM YIELDS (TONS/HECTARE) WITH DIFFERENT MANAGEMENT PRACTICES

	High potential areas: Local seed	High potential areas: Hybrid seed with appropriate management	Low potential areas: Local seed	Low potential areas: Improved seed with appropriate management
Kenya	Kitale Agricultural Research Station		Katumani Agricultural Research Station	
Maize	2.1	8.6 (KSC511)	0.9	4.5 (KCB)
Sorghum			0.7	1.4*
Malawi	Kasungu ARS (Average of 2 FAO trials)		Blantyre ADD average yields 1990/91	
Maize	1.1	3.0 (MH17)	0.7	2.3
Sorghum			0.5	1.5
Zimbabwe			Matopos Research Station	
Maize	2.4	7.5 (SR52)	1.1	3.6 (R201)
Sorghum			0.6	2.9 (SV1)

Source: Research stations as listed. Data relate to 1991 trials. Except for Zimbabwe, Matopos, data are for on-farm trials only. In the trial marked*, unimproved seed was used with different management methods.

Notes: Appropriate management is taken as: early planting, correct spacing, 40 kg. $P_{2O}5$ and 40 Kg N per hectare, intensive weeding unless otherwise specified.

So far as the second argument is concerned, a quick look at the available yield data suggests that even when population density figures are appropriately corrected for the carrying capacity of the land, the expected correlation between population density and food-crop yields does not hold. As will be apparent from Table 2, if average grain yield levels are computed for those sub-Saharan countries defined by Biswanger and Pingali (1989) as having 'high', 'medium' and 'low' agroclimatic densities respectively, the result is opposite to that expected, with the sample of low-density countries having on average slightly higher yields than the sample of high-density countries[5].

On the argument so far, then, yield increases are precluded neither by an absence of appropriate technologies nor by 'relative abundance of land', even supposing that to be an accurate description of the African condition. The fact remains, however, that performance has been poor, and we are therefore driven to look for an alternative explanation. The key to our approach will be the argument that the high-yielding technical packages described in Table 1 require amounts of money which local capital markets, operating under conditions of high risk, are ill-equipped to provide. Under such conditions any technical changes which occur are more likely to be policy-induced than spontaneously induced, as the conventional approach prefers, by population pressure. This argument will be pursued through detailed examination of three African countries: two towards the top end of Table 2's yield spectrum (Kenya and Zimbabwe) and the other, Malawi, towards the bottom, even though it is one of the most densely populated countries in Africa. These countries are selected for analysis, not only because of this contrast but more importantly because although no African country has really good crop yield data, the data for the three countries mentioned are better than the average in the sense that attempts are made to cross-check results by means of alternative estimation methods. A full discussion of this issue is given in Appendix 1.

II. ANALYTICAL FRAMEWORK

Consider a farm household which has three potential sources of income: growing a modern variety of food crop (Y_m), growing a traditional variety (Y_t), and off-farm income (Y_o).

---

5 Alexandratos has argued that although there is no correlation for African countries between yields for the period indicated or indeed the 1980s as a whole, such a correlation is indeed apparent for the 1970s and for the entire period 1961-90.

Table 2: GRAIN YIELDS IN RELATION TO POPULATION DENSITY IN SELECTED SUB-SAHARAN AFRICAN COUNTRIES, 1988-90

	Grain yield per hectare (kg/ha; 1988-90 average)
'High-density countries'	
Kenya	1 722
Ethiopia	1 199
Nigeria	1 172
Rwanda	1 102
Malawi	1 110
Sub-group average	1 261
'Medium-density countries'	
Zimbabwe	1 540
Ghana	1 027
Tanzania	1 391
Sierra Leone	1 344
Gambia	1 204
Sub-group average	1 301
'Low-density countries'	
Zaire	758
Zambia	1 841
Cameroon	1 232
Madagascar	1 918
Côte d'Ivoire	884
Sub-group average	1 326

Source: Grain yield is 'average, all cereals' from FAO (1992).

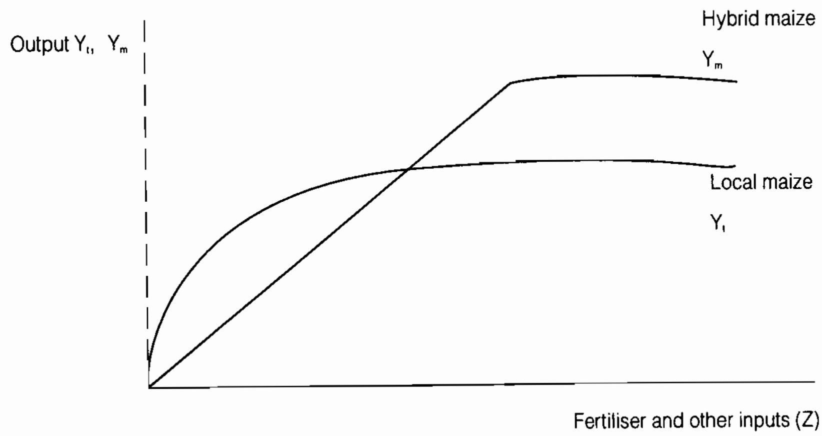
Population density is the 'agroclimatic labour density' defined as the number of agricultural workers per million calories of production potential, and is from Biswanger and Pingali (1989).

Total income is the sum of these three:

$$Y = Y_t + Y_m + Y_o \quad (1)$$

The factors of production are land (N), labour (L), and other inputs such as fertilisers (Z). Off-farm income is produced using labour alone, and the traditional and modern varieties of the crop require all three inputs. But the production functions for the two varieties are very different. Modern varieties respond less to fertiliser and other inputs at low, and more at high, levels of application[6]. If for reasons of capital market imperfection, or otherwise, the farm household is constrained to low levels of 'other inputs', it may well find itself locked into production of the traditional variety, as in Figure 1.

Figure 1: RESPONSE OF TRADITIONAL AND MODERN VARIETIES OF MAIZE AND SORGHUM TO FERTILISERS



Source: Alexandratos (1991)

6 Data suggesting that yield curves may cross in this way are presented by Conroy (1992), Table 10.32 for Malawian maize. Nadar and Faught (1984) for Kenyan maize, and Osmanzai (1991) for sorghum and millet in Zimbabwe. Contradictory evidence is however, presented by Smale et al. (1991), pp.33ff in respect of maize trials in Malawi, who suggested that hybrid yields may be superior at all levels of complementary input.

We now consider the nature of the rural capital market, specifically as it bears on the possibility of purchasing 'recommended' technical packages such as those whose potential is illustrated by Table 1. The cost of these at current market prices in relation to prevailing average rural income levels in 1991 for important maize-producing areas in our three sample countries was as set out in Table 3.

Table 3: KENYA, MALAWI AND ZIMBABWE: COST OF RECOMMENDED TECHNICAL PACKAGES IN RELATION TO AVERAGE FAMILY INCOME, 1991

	Cost of recommended technical package for maize	Average annual rural family income 1991
	(US$)/ha)	(US$)
Kenya (katumani)	63	305
Malawi (Kasungu)	68	96
Zimbabwe	76	276

Source: Cost of technical packages: as for Table 1.
Average rural incomes: Kenya: Government of Kenya (1991);
Zimbabwe, *Second Annual Report of Farm Management Data for Communal Area Farming Units,* 1989/90 Farming Sector, MLARR Farm Management Research Section; Malawi, Conroy (1992).

* Income from all sources. Gross marketed production divided by number of households, plus allowance for off-farm income and on-farm consumption.

Note: Small farms are defined as farms of less that 5 hectares (Kenya, Malawi); communal and resettlement areas (Zimbabwe).

Will a farmer farming 1½ hectares - the average 'small farm' size in the countries to be examined - be able to finance such packages? For most, the answer is no. Given that the cost of planting *one hectare* of maize to modern varieties with recommended management practices, as shown above, ranges between one-quarter and two-thirds of total annual family income, the possibility of financing such purchases out of savings will necessarily be confined to a few individuals, which leaves purchases on credit as the only remaining option[7]. Access to credit, in other words, is likely to be a crucial additional element in the production function for modern varieties. In each of the three countries investigated, and we suspect the rest of sub-Saharan Africa as well, the agricultural credit market consists of three parts: commercial banks who lend only to estate-owners and not to small farmers, informal money-lenders whose dealings are confined to short-term loans and often to their own village, and agricultural development banks - to which more recently have been added experimental 'quasi-formal' operations normally financed by aid donors or NGOs[8]. Only the third of these, therefore, is a realistic option for most small-holders; but only for a minority, as agricultural development banks throughout Africa have suffered from bad project selection and chronic arrears problems, with the consequence that it has been difficult for them to sustain and develop their operations, and hence credit is not available to all those willing to pay the market price for it. In addition, such institutions will generally only lend to those possessing a secure title to their land, which immediately cuts out all those farming land in communal tenure and a majority of women farmers. (Table 4 gives details of those taking, and wishing to take, credit for agricultural production in our three sample countries.) For those willing to borrow but unable to do so, the capital market fails, and the propensity to purchase modern-variety packages will depend on prospective yields in relation to affordability (the gap between output and input prices), and in relation to alternative off-farm income opportunities.

---

7 The following table from fieldwork carried out by Conroy (1992) on 685 smallholder households in Mzuzu, Kasungu, Lilongwe and Liwonde districts, Malawi, dramatically illustrates the relationship between credit use and yields in smallholder areas of Malawi:

(per household)	Credit recipients	Non-credit recipients
Kg. fertiliser	273	21
Kg. hybrid seeds	12	0.6
Holding size (hectares)	1.5	1
Income (Malawi Kwache)	451	212

Source: Conroy (1992) Table 8.10, p. 269. For non-African evidence on the link between credit and the adoption of agricultural innovations, see Feder, Just and Zilbermann (1985).

8 On Malawi, see Chipeta and Mkandawire (1992); on Zimbabwe, see Chimedza (1990).

Table 4: KENYA, ZIMBABWE AND MALAWI: PROPORTION OF SMALLHOLDER FARMERS USING AND DESIRING CROP LOANS (SAMPLE DATA)

	Zimbabwe	Malawi	Kenya
Proportion of smallholder farmers using credit	26	18	22
Proportion wishing to have credit	50	59	72

Source: Zimbabwe, Bratton (1986); Malawi, Conroy (1992), chapter 8; Kenya, World Bank (1989).

The argument so far can be summed up by means of Figure 2. In part (a) of the diagram, individuals FG receive credit, but there is an excess demand EF for credit at the institutionally fixed interest rate: for these individuals, the credit market is 'missing'[9]. The number of individuals who have access to credit, together with the level of output and input prices, determines the position of the budget constraint, XX'. The optimal technology with this budget constraint is BB': mainly traditional varieties. Were the credit constraint to be relaxed to the extent of allowing a number of farmers HJ to be able to borrow - which paradoxically might be best achieved by *raising* the interest rate[10] for formal sector credit - this would move the budget constraint out to YY'[11], and the optimal choice of technology would become AA', consisting mainly of modern varieties. The same result could alternatively be achieved by *either:*

(i) a relaxation in the liquidity constraint achieved through a general increase in output prices, or a general reduction in input prices; or

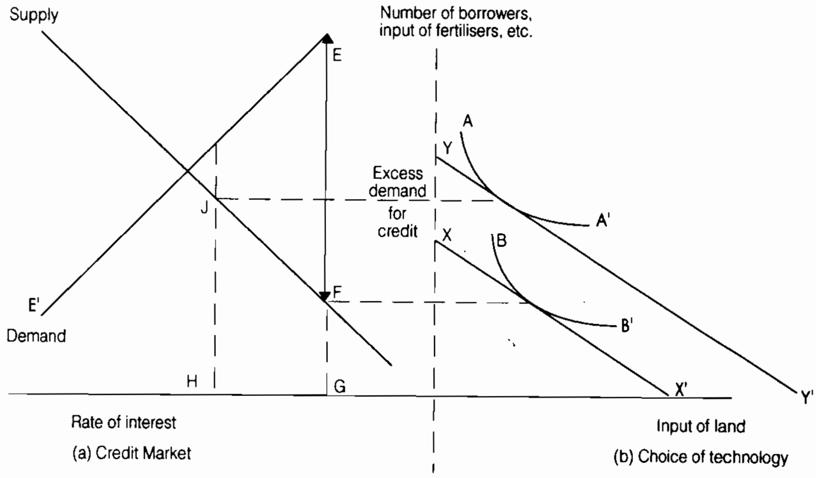
[9] This may result from the rationing of households in the credit market because of potential default (Stiglitz and Weiss, 1981). The demand curve, EE' is defined by the rate of return which farmers expect to be able to earn on investment in modern inputs. The curve drawn in Figure 2 should be interpreted stochastically, as an average of the subjective expectations of all farmers; for risk-loving farmers it will the further to the North-West than for risk-averse farmers (Biswanger and Sillers, 1983).

[10] Or by reforms facilitating farmers' access to the informal credit market. See Appendix 2.

[11] Note that if (as we assume) the interest rate rises as credit is expanded, the budget line will not only move outwards but twist anti-clockwise to reflect the increased cost of credit as depicted in Figure 2. Hence budget constraints XX' and YY' are deliberately not drawn parallel to one another.

(ii) a shift in relative factor prices making 'fertiliser and other modern inputs' cheaper and land dearer (not shown on the diagram), as in standard induced-innovation theory (eg. Ruttan and Thirtle 1989).

Figure 2: CREDIT MARKET AND TECHNOLOGICAL CHOICE IN FOOD CROP AGRICULTURE



It will be clear from the analysis so far, therefore, that changes in relative input prices are not the only route, nor perhaps the most important, by which technical changes may be induced.

We now proceed with the formal specification of the model in order to produce hypotheses suitable for testing. The farm household is assumed to maximise total net expected income:

$$E(Y) = E(Y_t + Y_m + Y_o)$$

subject to the constraints:

Net income from traditional varieties: $Y_t = P_o f\,(N,L,Z,W) - (P_n N_t + P_l L_t + P_z Z_t)$ (2a)

Net income from modern varieties: $Y_m = P_o g\,(N,L,Z,C,W) - (P_n N_m + P_l L_m + P_z Z_m)$ (2b)

Off-farm income: $Y_o = h(L)$ (2c)

Cash-flow constraint (all income to be financed from current income, savings or credit): $S + C + Y = P_n N + P_l L + P_z Z$ (2d)

where the notation employed is the following:

Y_t output of traditional varieties

Y_m output of modern varieties

Y_o off-farm income

N land acreage

[N_t: allocated to traditional varieties,
N_m: allocated to modern varieties]

L labour input

[L_t: allocated to traditional varieties,
L_m: allocated to modern varieties]

Z supplementary inputs capable of increasing yield [fertiliser, pesticides, irrigation water, etc.]

[Z_t: allocated to traditional varieties,
Z_m: allocated to modern varieties]

S savings held by farmers

C credit available to farmers

P_n, P_l, P_z prices of land, labour and 'modern inputs' respectively

P_o Price of grain paid to farmers (assumed constant as between modern and traditional variety)

f( ) production function for traditional varieties

g( ) production function for modern varieties

Maximising (1) subject to the constraints (2a) - (2d), the Lagrangean is

$$\theta = (Y_t + Y_m + Y_o) + \lambda_1 (Y_t - [P_o f(N, L, Z, W) -$$

$$(P_n N_t + P_l L_t + P_z Z_t] + \lambda_2 (Y_m - [P_o g (N, L, Z, C, W)-$$

$$(P_n N_m + P_l L_m + P_z Z_m)] + \lambda_3 (Y_o - h (L))$$

$$+ \lambda_4 (S + C + Y - (P_n N + P_l L + P_z Z) \qquad (3)$$

where λ_1 to λ_4 are the Lagrange multipliers attaching to the constraints (2a) to (2d) respectively. Taking partial derivatives of (3) with respect to the exogenous variables and setting them equal to zero, we reach the following first-order conditions for a maximum, assuming that an interior solution exists and that all constraints are binding:

$$\frac{\partial \theta}{\partial N} = \lambda_1 P_o \frac{\partial f}{\partial N} + \lambda_2 P_o \frac{\partial G}{\partial N} + \lambda_4 P_n = 0 \qquad (4a)$$

$$\frac{\partial \theta}{\partial L} = \lambda_1 P_o \frac{\partial f}{\partial N} + \lambda_2 P_o \frac{\partial G}{\partial N} + \lambda_4 P_1 = 0 \qquad (4b)$$

$$\frac{\partial \theta}{\partial Z} = \lambda_1 P_o \frac{\partial f}{\partial N} + \lambda_2 \frac{\partial G}{\partial Z} + \lambda_4 P_z = 0 \qquad (4c)$$

$$\frac{\partial \theta}{\partial C} = \lambda_2 \frac{\partial g}{\partial C} + \lambda_4 = 0 \qquad (4d)$$

$$\frac{\partial \theta}{\partial W} = \lambda_1 P_0 \frac{\partial f}{\partial W} + \lambda_2 \frac{\partial G}{\partial W} = 0 \qquad (4e)$$

$$\frac{\partial \theta}{\partial \lambda_1} = Y_T - P_o f (N, L, Z, W) - (P_N N_t + P_l L_t + P_z Z_t) = 0 \qquad (4f)$$

$$\frac{\partial \theta}{\partial \lambda_2} = Y_m - P_o\, g\,(n, L, Z, C, W) - (P_n N_m + P_l L_m + P_m Z_m) = 0 \quad (4g)$$

$$\frac{\partial \theta}{\partial \lambda_3} = Y_o - h\,(L) = 0 \quad (4h)$$

$$\frac{\partial \theta}{\partial \lambda_4} = S + C + Y - P_n N - P_l L - P_z Z \quad (4k)$$

Our ultimate objective is to find out how the variables in this system, and in particular, output per acre ($^Y/N$) will respond when the equilibrium depicted by equations (4a) to (4k) is disturbed. We thus proceed to calculate the reduced form of the system. First, if one substitutes for all the λ terms in (4a) to (4e), (4e) becomes[12]:

---

12 Derivation:

I $\quad \lambda_4 = -\lambda_2 \dfrac{\partial G}{\partial C}$ from (4d)

Substituting this in (4b)

II $\quad \lambda_2\, p_o \left(\dfrac{\partial G}{\partial N} - \dfrac{\partial G}{\partial C}\, pl\right) = \lambda_1 p_o \dfrac{\partial f}{\partial N}$

whence:

III $\quad \lambda_1 = \dfrac{p_o \lambda_2 \left[\dfrac{\partial G}{\partial N} - \dfrac{\partial G}{\partial C}\, pl\right]}{p_o \dfrac{\partial f}{\partial N}}$

Substituting now in (4e)

IV $\quad \dfrac{\lambda_2\, p_o \left[\dfrac{\partial G}{\partial N} - \dfrac{\partial G}{\partial C}\, pl\right]}{p_o \dfrac{\partial f}{\partial N}}\, p_o \dfrac{\partial f}{\partial W} + \lambda_2 \dfrac{\partial G}{\partial W} = 0$

Hence

$$\lambda_2 \frac{\partial G}{\partial W} = \lambda_2 \frac{\dfrac{\partial G}{\partial C}\, pl - \dfrac{\partial G}{\partial N}}{\dfrac{\partial f}{\partial N}}\, p_o \frac{\partial f}{\partial W}$$

$$\frac{\partial f}{\partial N} = \frac{\left(\frac{\partial G}{\partial C} P_1 - \frac{\partial f}{\partial W}\right)}{\partial G/\partial W} \quad p_o \frac{\partial f}{\partial W} \tag{5}$$

Differentiating (2a) and (2b):

$$\partial Y_m = \frac{\partial g}{\partial N} dN + \frac{\partial g}{\partial L} dL + \frac{\partial g}{\partial Z} dZ + \frac{\partial g}{\partial C} dC + \frac{\partial g}{\partial W} dW \tag{6a}$$

$$\partial Y_T = \frac{\partial f}{\partial N} dN + \frac{\partial f}{\partial L} dL + \frac{\partial f}{\partial Z} dZ + \frac{\partial f}{\partial W} dW \tag{6b}$$

Substituting from (5), and using the principle that

$$\frac{d(Y_m + Y_T)}{dN} = \frac{\partial Y_m}{\partial N} + \frac{\partial Y_T}{\partial N} \quad ,$$

$$dY = \frac{\frac{\partial G}{\partial C} P_1 - \frac{\partial G}{\partial N} p_o \frac{\partial f}{\partial W}}{\partial G/\partial W} \quad dN + \frac{\partial g}{\partial N} dN \tag{7}$$

or

$$\frac{dY}{dN} = \frac{\frac{\partial G}{\partial C} P_1 - \frac{\partial G}{\partial W} \ p_0 \ \frac{\partial f}{\partial W}}{\partial G/\partial W} + \frac{\partial g}{\partial N} \tag{7'}$$

Cancelling out the λ_2 and multiplying by

$$\frac{\partial f}{\partial N} \Big/ \frac{\partial G}{\partial W}$$

we have

$$\frac{\partial f}{\partial N} = \left(\frac{\frac{\partial G}{\partial C} \ pl - \frac{\partial G}{\partial N}}{\frac{dG}{\partial W}}\right) P_o \frac{\partial f}{\partial W}$$

the expression quote as (5) in the text.

Expression (7) is the relationship that we shall want to examine in the remainder of this paper. In essence, it is a formalisation of Figure 2. Changes in income per acre of land (dY/dN) are induced not only by changes in relative factor prices and, in particular, the cost of labour, (p_l) but also by changes in the price of output in relation to purchased inputs (p_o), by the availability of credit and the response of modern varieties output to credit $\left(\frac{\partial G}{\partial C}\right)$, the productivity of hybrids in relation to traditional varieties, and of course, by weather. All of these except for the last two are potentially or actually policy variables, and to that extent, innovation can be seen as policy-induced. We list these parameters with their meaning and expected sign, for future reference, in Table 5.

TABLE 5: PARAMETERS WHICH DETERMINE VARIATION IN CROP YIELDS IN EQUATIONS (7) AND (7')

Parameter Symbol	Description	Introduced in equation	Expected sign of effect on Y/N	Empirical estimates displayed in Table
P_1	Cost of agricultural labour	(2d)	-	A-2 to A-4
P_o	Output price in relation to cost of fertiliser and other inputs	(2a, 2b)	+	A-2 to A-4
$\frac{\partial G}{\partial N}$	Yield increase derivable from modern varieties	(2b)	+	A-2 to A-4
$\frac{\partial f}{\partial W}, \frac{\partial G}{\partial W}$	Production response of traditional and modern varieties respectively to weather conditions	(4e)	+	1-2 to A-4
$\frac{\partial G}{\partial C}$	Responsiveness of modern varieties to credit	(4d)	+	A-2 to A-4

III. EMPIRICAL INVESTIGATIONS

The Data

In Table 6 we set out estimates of yield levels for the past 30 years for Kenya, Malawi and Zimbabwe. A full discussion of data sources containing details of the estimation methods used and a commentary on the degree of confidence that can be placed on each of them is given in Appendix 1.

Table 6: KENYA, ZIMBABWE AND MALAWI: MAIZE AND SMALL GRAINS YIELDS (TONS/HECTARE; FIVE-YEAR AVERAGES)

Period	KENYA		MALAWI		ZIMBABWE	
	Maize	Sorghum	Maize	Sorghum	Maize	Sorghum
1960-75	1.48	-	1.00	-	1.18	0.66
1966-70	1.75	-	1.12	-	(1.26)[a]	0.75
1971-75	1.90	-	1.05	-	1.84	0.69
1976-80	1.87	0.74	1.04	0.60	1.53	0.65
1981-85	1.78	0.80	1.15	0.76	1.40	0.45
1986-90	2.17	0.58	1.10	0.60	1.55	0.54
Rate of change 1986-90 in relation to 1960-65 (% p.a.)	1.9	-2.2	0.6	0.0[b]	1.2	-1.7

Source: Appendix 1, Table A-1 to A-3 below.
Notes: denotes data for full five-year period not available.
[a] Average of 1966 and 1970 only; [b] for intervening years, data on large farm yields only available.

For sorghum, yield data are only available since the middle 1970s, but those data we have suggest yields to be almost invariably low by world standards (only surpassing 1 ton/hectare in an unusual year) and, if anything, on a declining trend in all three countries. This finding parallels the trend reported for Western Africa by Matlon (1990). For maize, the trend is upward as between the early 1960s and the late 1980s in all three countries, but in Malawi, insignificantly so. In Kenya, on the other hand, the trend growth rate of 1.9 per cent per annum for maize yields rivals that achieved by India and other Asian countries during the same period. What we have, to be precise, are Asian rates of application of modern varieties in Kenya and Zimbabwe,[13] Asian rates of productivity growth in Kenya only, but a very un-Asian and persisting differential in yields between large and small farms in all three countries. Table 7 shows this differential to be significant in both Kenya and Zimbabwe.

[13] Thirtle et al. (1993) quote a 95 per cent usage of hybrid maize seed in communal areas of Zimbabwe; Karanja (1990) quotes a 70 per cent hybrid seed utilisation rate for Kenyan small farm areas.

Table 7: SUMMARY TABLE: LARGE VS. SMALL FARM YIELDS (KG/HA)

	Zimbabwe						Kenya		
	Maize			Sorghum			Maize		
	(1) Commercial Areas	(2) Communal Areas	(3) Ratio (1)/(2)	(1) Commercial Areas	(2) Communal Areas	(3) Ratio (1)/(2)	(1) Rift Valley (Mainly large farms)	(2) Other provinces (Mainly small farms)	(3) Ratio (1)/(2)
1970-4	4 103	573	7.2	873	426	2.1	2 621	1 460	1.8
1975-9	4 460	666	6.7	2 075	456	4.5	2 964	1 610	1.8
1980-4	3 620	586	6.2	2 005	342	5.8	2 517	1 460	1.7
1985-9	4 333	998	4.3	-	-	-	2 623	1 770	1.5
Whole period 1970-9	4 129	705	5.8	1 651	408	4.0	2 681	1 575	1.7

Source: Kenya: Central Bureau of Statistics. 'Other provinces' in high potential area are: Central, Western and Nyanza.
Zimbabwe: Government of the Republic of Zimbabwe (1989).

Time-series Regression Analysis

We now examine, using regression methods, changes in yields over time in terms of the variables emerging from the model of the previous section and listed in the summary Table 5 above. The results of this exercise are shown in Tables 8a and 8b, using ordinary least squares analysis as there are no obvious simultaneities involved. For maize, the results in Table 8a suggest that between 66 and 75 per cent of the variance in aggregate maize yields, according to country, can be explained by the variables included in our model, even in its present crude form without lags. Although all variables have the 'right sign', in terms of the expectations set out in Table 5, the coefficients on the real agricultural wage rate and (for individual countries) the weather are insignificant. The ratio of output to input prices is significant in all three countries, as are credit disbursements to the small farm sector in Kenya and Zimbabwe, suggesting that these policy-related variables have a role to play in explaining yields over and above the influence of relative factor prices. On the argument presented in Figure 2 above, this influence operates through the provision of liquidity which enables the farmer to overcome the obstacle of imperfection in the capital market. For sorghum, broadly the same story holds good but the equations are much less well estimated: the r^2's are below 25 per cent, and the index of sorghum prices and the ratio of hybrid to local seed yields, although of the right sign, are insignificant in all cases. Credit is a significant determinant of yields in the case of Kenya only. Indicators of input (seed and fertiliser applications) show much better correlation with the chosen independent variables than grain yields, suggesting that in some environments increased inputs of seed and fertiliser do not produce proportionate increases in yields. This is a fundamental problem, and will be further taken up in cross-section analysis below. Two obvious econometric problems need to be corrected: the automatic and spurious correlation between those series that are not stationary (i.e., maize yields in Kenya and Zimbabwe, and credit disbursements in all the selected countries) and the Durbin-Watson statistics for Malawi and pooled data within the maize regression, which indicate the presence of serial correlation in the residuals. We tackle these problems by the simplest route, of estimating the regression equation in first differences. If this is done (Table 8c) the Durbin-Watson statistics move sufficiently close to 2 to suggest that the problem of serial correlation has been eliminated. The r^2's (except for Malawi) increase also. The pattern of results is not greatly altered if the large farm areas of Kenya and Zimbabwe are excluded from the regression, except that the coefficient on the wage rate becomes (perversely but insignificantly) positive. On the superficial evidence of Table 8c, an increase of 1 ton/hectare in maize can be produced *ceteris paribus* by either an increase of 32 percentage points in the ratio of maize to fertiliser prices or an increase of 71,000 in the number of small farmers receiving credit. But other things, of course, may not

Table 8a: DETERMINANTS OF MAIZE YIELDS: RESULTS OF REGRESSION ANALYSIS
(Dependent variable: average maize yield for each country (tons/ha)
(Ordinary least squares estimation)

Data set	Period covered	Number of observations	Regression coefficient on independent variables: (Student's t-statistics under coefficient in brackets)						r^2	D.W.
			Constant	Real agricultural wage rate	Real maize price (index 1980=100)	Credit disbursements (1) (value of loans to small farmers in 1980 £'000)	Ratio of yields under hybrid to yields under local seed	Weather (average rainfall in mm. at selected weather stations)		
Kenya	1960-91	32	1.09	-0.0015	0.042*	0.063	0.17*	0.0019	0.75	1.5684
			(6.72)	(0.48)	(2.17)	(2.06)	(2.12)	(1.68)		
Malawi	1960-91	32	0.24	-0.013*	0.0042**	0.0016	0.13*	0.0005	0.86	1.3073
			(2.59)	(2.33)	(8.37)	(1.25)	(3.00)	(0.05)		
Zimbabwe	1960-91	32	0.34	-0.012	0.048*	0.018**	0.13	0.0027	0.79	1.6004
			(1.32)	(0.74)	(2.16)	(2.45)	(1.24)	(0.19)		
Pooled	1960-91	96	0.49*	0.013**	0.027	0.08*	0.14**	0.004**	0.66	(0.9426)
data			(4.60)	(4.99)	(2.78)	(1.80)	(4.93)	(3.31)		
				relative factor prices	policy variables		biological conditions			

Source: are given in full in Statistical Appendix, Tables A-1 to A-4.

Symbols: * denotes significance of a coefficient at the 5% level; ** denotes significance at the 1% level; A bracketed Durbin-Watson Statistic indicates that the residuals are serially correlated.

Table 8b: DETERMINANTS OF SORGHUM YIELDS: RESULTS OF REGRESSION ANALYSIS
(Dependent variable: average sorghum yield for each country (tons/ha)
(Ordinary least squares estimation)

Data set	Period covered	Number of observations	Regression coefficient on independent variables: (Student's t-statistics under coefficient in brackets)						r^2	D.W.
			Constant	Real agricultural wage rate	Real sorghum price (index 1980=100)	Credit disbursements (1) (value of loans to small farmers in 1980 £'000)	Ratio of yields under hybrid to yields under local seed	Weather (average rainfall in mm. at selected weather stations)		
Kenya	1960-91	32	0.60*	-0.01*	0.029	-0.012*	0.28	0.009	0.21	1.7781
			(2.33)	(1.97)	(0.96)	(2.17)	(2.18)	(0.52)		
Malawi	1960-91	32	-0.10	-0.031*	0.02	0.031	0.15	0.007	0.24	1.5323
			(0.38)	(1.73)	(1.29)	(1.73)	(1.11)	(0.25)		
Zimbabwe	1960-91	32	0.61*	-0.023	0.007	0.012	-0.032	0.0029	0.15	1.9632
			(2.80)	(1.61)	(0.38)	(0.60)	(0.37)	(1.05)		
Pooled	1960-91	96	0.61**	-0.0023	0.042	-0.0012	0.012	0.010	0.06	1.6862
data			(6.77)	(1.02)	(0.51)	(0.33)	(0.54)	(0.95)		
				relative factor prices	policy variables		biological conditions			

Source: are given in full in Statistical Appendix, Tables A-1 to A-4

Symbols: * denotes significance of a coefficient at the 5% level; ** denotes significance at the 1% level; A bracketed Durbin-Watson Statistic indicates that the residuals are serially correlated.

Table 8c: DETERMINANTS OF MAIZE YIELDS: RESULTS OF REGRESSION ANALYSIS
(Dependent variable: year on year change in average maize yield for each country)

$\frac{Q}{A_t} - \frac{Q}{A_{t-1}}$. Ordinary least squares estimation

Data set	Period covered	Number of observations	Regression coefficient on independent variables: (Student's t-statistics under coefficient in brackets)						r²	D.W.
			First Differences in:							
			Constant	Real agricultural wage rate	Maize/fertiliser price ratio	Value of loans (1) to small farmers (1980 £'000)	Ratio of yields under hybrid to yields under local seed	Weather (average rainfall in mm. at selected weather stations)		
Kenya	1960-91	31	-0.007	-0.003	0.033*	-0.012**	0.12*	0.0077	0.69	2.0516
			(0.01)	(0.18)	(1.80)	(3.35)	(1.61)	(0.67)		
Malawi	1960-91	31	0.009	-0.01	0.38**	0.048	0.17**	0.0006	0.84	2.2168
			(0.02)	(0.13)	(8.38)	(0.61)	(4.33)	(0.87)		
Zimbabwe	1960-91	31	-0.0022	-0.0025	0.035*	0.052*	0.23*	0.001	0.83	2.1416
			(0.037)	(0.32)	(1.54)	(1.88)	(2.11)	(0.32)		
Pooled	1960-91	93	-0.005	-0.0014**	0.031**	0.014*	0.27**	0.0003	0.80	
data			(0.24)	(4.77)	(3.81)	(2.50)	(7.44)	(0.33)		
Pooled	1960-91	93	0.0022**	0.002**	0.003**	0.015**	0.028	0.0004	0.62	2.5225
data, small farm areas only[a]			(0.11)	(6.18)	(3.85)	(2.56)	(0.24)	(0.47)		
				relative factor prices	policy variables		biological conditions			

Source:are given in full in Statistical Appendix, Tables A-1 to A-4.

[a] The data set used for this regression is: Zimbabwe, communal areas; Kenya, maize farms outside Rift Valley Province; Malawi, all maize farms (for data and sources, see Table 7).

Symbols: * denotes significance of a coefficient at the 5% level; ** denotes significance at the 1% level; A bracketed Durbin-Watson Statistic indicates that the residuals are serially correlated.

be equal: this is a single equation model, and although we have assumed no important simultaneities in the system, it would be important to ascertain the extent of feedbacks before using it as a guide to policy.

Cross-section Analysis: Interactions Within the Credit Market

The time series relationships estimated in Tables 8a and 8c, not surprisingly in view of the data problems involved, fall short of a desirable level of goodness of fit or, in all probability, of predictive power. It would therefore be of particular value to check them by cross-section methods wherever possible; however, this is not possible for many of the variables in Table 6, since, under the marketing systems which prevailed in all three countries, input and output prices, at least on the official market, are the same for all farm families at any given time. However, conditions in credit markets do vary between regions and countries, hence the component of the model which deals with the capital market can be checked in this way; and if one takes a realistic view and goes beyond a simple measurement of conditions prevailing in *formal* credit markets to examine the *total* availability of credit (as is done in Appendix 2 below) cross-section analysis becomes a necessity, as we do not have time series data on conditions in African informal credit markets. This section takes a few halting steps in this direction.

We begin by comparing yields in districts which have similar natural resource environments but differential access to credit. This is attempted for Malawi and Zimbabwe in Table 9 on the basis of cross-section data for 1990-91 and 1989-90 respectively. We discover that for these two years, as between the two smallholder regions in the high-rainfall natural region IIa of Zimbabwe, the Chiweshe area, which had better access to credit, had markedly higher yields, whereas in Malawi, the two central Agricultural Development Divisions of Kasungu and Lilongwe have higher maize yields and better access to smallholder credit than any other part of the country even though they have lower average rainfall than any other part of the country except for Ngabu in the South. These figures do not, of course, prove that access to credit is the crucial causal factor in determining yields, as other potential causes have not been held constant, but they do constitute additional evidence for the proposition that the capital market constraint should be taken seriously.

We now consider evidence on the relationship between the quasi-formal and the informal parts of the credit market. The key issue which needs to be resolved is: how is the relationship between credit flows and farmers' yields affected by the existence of a large and thriving population of rural moneylenders? In Appendix 2 below, we demonstrate that the relationship between formal and informal-sector credit volumes is not pre-determined: the advent of a quasi-formal lender may cause informal money lenders to shrink their volume

Table 9: MALAWI AND ZIMBABWE: SMALLHOLDER AND SORGHUM YIELDS IN RELATION TO CREDIT INFLOWS AND NATURAL RESOURCE CONDITIONS

Malawi (1990/1 cropping season)								
Districts:	Karonga	Mzozu	Kasungu	Lilongwe	Salima	Lilongwe	Blantyre	Ngabu
Average yield: Maize	1.02	1.23	1.34	1.24	1.26	1.02	0.88	0.71
(tons/ha) Sorghum	0.48	-	-	-	0.65	0.32	0.49	0.71
% of smallholders borrowing from smallholder agricultural credit administration	29	24	30	31	23	15	16	12
Average rainfall 1979/80 to 1990/91 (mm.)	981	1 422	848	956	1 199	1 054	1047	820

Source: Smallholder Agricultural Credit Administration; *Malawi Agricultural Statistics* 1992 Edition, Table 2.4; Malawi Meteorological Office.

Zimbabwe (1989/90 cropping season						
Sample area:	Buhera	Chirau	Chirumanzo	Chiwerhe	Nyajena	Zuishava
Average yields: Maize	1.16	1.23	2.16	2.27	0.34	0.98
(tons/ha) Sorghum	0.64	-	-			
% of householders received Agricultural Finance Cooperation loan 1989/90	-	12.0	51.8	51.8	3.3	..
Natural Region	IV	IIa	III	IIa	IV	V
(Annual rainfall mm.)	450-650	750-1 000	600-800	750-1000	450-650	<450

Source: GRZ (1992), Tables 1.6; 3.2; 4.7.

of lending (because they 'surrender' business they have lost) or to increase it (because they decide to compete aggressively by venturing into new markets, and reducing their profit margin among existing lenders, and because of income effects). Which of the two effects predominates is of considerable empirical importance. Preliminary fieldwork results from Kenya and Zimbabwe suggest that in practice, the relationship may often be complementary rather than competitive. Table 10, derived from interviews with a small number of moneylenders in regions where quasi-formal institutions had recently started to provide credit, shows that their response was more frequently to expand their volume of business than to reduce it:

Table 10: TWO REGIONS OF KENYA AND ZIMBABWE: MONEYLENDERS RESPONSES TO THE QUESTION "HAS YOUR VOLUME OF LENDING INCREASED IN THE LAST YEAR?"

Kenya (Chogoria)		Zimbabwe (Chiweshe)	
Yes	82%	Yes	73%
No	18%	No	27%
Among those answering Yes:		Among those answering Yes:	
Reduced interest rates	71%	Reduced interest rates	65%
Actively looked for new borrowers	56%	Actively looked for new borrowers	77%
Sample size	17		22

Sources: Interviews in Chogoria (Meru district, Kenya) and Chiweshe (Central Mashonaland province, Zimbabwe), October 1992.

Notes: In both of the districts under study, a quasi-formal credit organisation (Presbyterian Church of East Africa, Zimbabwe Agricultural Finance Corporation) had set itself up or expanded its operations in 1991-92.

Given the small size of the sample, these results can only be taken as illustrative; our research is currently in the process of expanding the sample size. It does appear, however, that in two of the countries under examination the relationship between the quasi-formal and informal credit market may be complementary rather than competitive, and if this is true, the variable defined as C in the preceding analysis (formal-sector credit disbursement) may be directly, and not inversely, related to the overall availability of credit to the rural economy.

Inter-country Comparisons

Although our research suggests that policy and capital market variables do exert an influence on grain productivity, that influence varies, on the evidence in Tables 8a - 8c, from country to country, and it is important to consider why. In particular, the influence of both the maize/fertiliser price ratio and credit disbursement on maize yields is both lower and less significant in Malawi than in Kenya and Zimbabwe. Indeed, in Malawi the classical 'modernising' *stimuli* of fertiliser, credit and a stimulative price policy have been made available on an increasing scale, as in Kenya and Zimbabwe, during the 1980s (Table A-5 below), and yet the apparent response of maize yields (Table 6) has been insignificant. Can the variables of our model explain this paradox?

So far as we can assess, the non-policy variables of Table 5 - weather, wage rates and the yield increase derivable from modern varieties - do not exhibit trends sufficiently different in Malawi from the other countries to provide a satisfactory explanation of Malawi's inferior performance[14]. We are therefore thrown back on two possible explanations which lie 'outside' our model. The first is that the hybrids available to Malawian smallholders do not taste or mill as well as local varieties, in spite of their higher yield, so that the incentive to use hybrids in production is less than appears from the significant difference in productivity; this has been argued with considerable vigour by Kydd (1989) and Smale *et al.* (1991). For this reason, hybrid utilisation is growing from a much lower base, being about 30 per cent for Malawi by comparison with over 70 per cent in both Kenya and Zimbabwe. The other is that a tendency for *hybrid* yields to rise for the reasons given by our model is counterbalanced by a falling trend in *local* maize yields caused by the declining fertility of the soil. This cuts the link between modern inputs and overall yields in countries such as Malawi where local maize usage is significant. The data of Table A-5 (Appendix 1) show that the demand constraints mentioned by Kydd and Smale have not stopped sales of hybrid seed from doubling between 1986 and 1991 and growing at a faster rate than in the other two countries. Moreover, farmers growing *hybrid* maize seed in Malawi have experienced

---

[14] In the three African countries under examination, the liberalisation of the 1980s made little difference to price incentives for maize and most other crops. Prices to farmers had been close to, if not in excess of, export parity since colonial times.

increasing yields over the 1980s, by contrast with the experience of the country as a whole[15]. However, the correlations between yield and use of modern inputs (seed and fertiliser) for Malawi as a whole are much lower than in Kenya and Zimbabwe,[16] partly because local maize does not respond to fertiliser as well as elsewhere but much more because the yields on unfertilised maize are falling, due to a decline in the fertility of the soil, at least as fast as hybrid yields are rising. A favourable stance of price and credit policy has not, so far, been able to override this handicap.

IV. IMPLICATIONS

It is common ground that recent economic development in sub-Saharan Africa has been stunted by comparison with other regions of the developing world, and that the poor performance of the food-crop sector has much to do with this. However, we believe that the arguments presented in this paper warrant a reconsideration of the idea that Africa is doomed to low crop yields by low population density and factor price ratios which as a consequence are unfavourable to the adoption of high-yielding varieties. We have argued from first principles, and empirical analysis appears to confirm, that in an environment where the investment required for the effective adoption of HYVs is large in relation to the farmer's income, access to credit and output/input price ratio will be key determinants of the adoption rate. Since both are heavily influenced by Government policies and institutions, innovation should appropriately be seen as policy-induced rather than merely induced by naturally-occurring input scarcities. A major policy offensive has, of course, been recently launched across the entire developing world by the World Bank under the name of

15 Yield data for Malawi (in tons per hectare) are the following:

	Local Maize	Hybrid Maize
1983-84	0.98	2.74
1984-85	1.03	-
1985-86	0.95	-
1986-87	0.95	2.70
1988-89	1.05	2.86
1989-90	0.93	2.55
1990-91	0.87	2.91

16 The correlation coefficients (r^2) between rates of fertiliser and overall maize yields are:

Kenya	0.92
Malawi	0.74
Zimbabwe	0.91

Datas for Tables 8a-8c.

'structural adjustment', aimed at raising productivity by liberalising output and input markets; but its results in relation to African agriculture appear to have been scanty (Lipton 1990) and the analysis of this paper may help us to see why: for liberalisation, in terms of the variables in Table 6, administers a boost by raising output prices but a negative shock by making inputs such as fertiliser more expensive for small farmers[17]. In relation to the capital market it simply by-passes the main problem, which is that in an inherently imperfect capital market many small farmers will not be able to acquire finance even for profitable projects. In such a market liberalisation will not improve access at the bottom end; nor, self-evidently, will a policy of simply pumping out state-subsidised loans in the general direction of small farmers. What is needed are institutions specially designed for the function of lending to small farmers without collateral and achieving high recovery rates even in conditions of considerable climatic uncertainty. Luckily, many new institutions of this type, including some in Africa, have shown promise in walking this difficult tightrope (Yaron 1991, Hulme 1990).

In conclusion, it is interesting to make an explicit comparison between the countries examined in this paper, where according to the general scholarly consensus the green revolution is still to come, and those of South Asia where it has already occurred. Such a comparison is made in Table 11 in respect of the independent variables featured in Table 6, plus one or two others. We note first of all that the difference in yield growth between India and Pakistan on the one hand, and at least Kenya and Zimbabwe on the other, is not dramatic: to speak of revolution in the one place and non-revolution in the other would appear inappropriate. Secondly, there is little significant difference between the African and Asian countries considered in respect of the yield gap between traditional and modern varieties, or in respect of input/output price ratios. In these respects, it is not appropriate to speak of either 'the natural environment' or 'policy' being more favourable to technical progress in South Asia than in Africa. There are differences between Asia and Africa, however, in respect of area irrigated, the yield differential between large and small farmers, and the proportion of farmers receiving institutional credit. Minor irrigation, HYV packages and credit are widely available to South Asian farmers; they are much less widely available to African farmers, and such green revolution as there has been is therefore in Africa very much more confined to large farms. An appropriately financed downward extension of the credit and agricultural inputs markets would therefore appear to be a major policy priority for African governments and international aid donors in the 1990s. As is illustrated by the

---

17 For an account of the World Bank and USAID attempts to abolish fertiliser subsidies in Malawi, see Harrigan (1991), Chapter 15. The problem is compounded by the fact that for political reasons liberalisation of input markets has been accomplished much more completely than liberalisation of output markets, so that the negative shock of dearer inputs and reduced state support has hit farmers well before the positive shock of higher prices and more open markets for their produce. Existing studies of structural adjustment and agriculture, including Lele (1989) do not adequately bring this fact out.

experience of India and Indonesia, whose agricultural prospects were widely dismissed in the 1960s but which are now net food exporters in the 1990s[18], it is not appropriate to despair of African prospects in this area simply because past performance has been sluggish. Appropriate policies, taking due note of innate imperfections in rural finance and input markets, may yet be able to bring about a turn-around of similar magnitude.

Table 11 GREEN REVOLUTIONS COMPARED: AFRICA VERSUS SOUTH ASIA

	India	*Pakistan*	*Kenya*	*Malawi*	*Zimbabwe*
Growth of grain output per hectare (per annum) 1988-90 in relation to 1961-3	3.6	1.5	2.5	0.6	2.4
Output per hectare (kg) 1988-90 average	1 861	1 744	1 722	1 110	1 540
Percentage of farmers receiving institutional loans (1990)	38	-	22	18	26
MV/TV yield ratio without fertilisers	1.2:1 (wheat) 1:1 (rice)	1.4:1 (wheat)	1.3:1 (maize)	1.1:1 (maize)	1.2:1 (maize)
Area irrigated (% of area under arable and permanent crops, 1990)	25.4	78.2	2.1	0.9	7.8
Fertiliser price/maize price ratio (1988)	-	-	4.5	10.3	1.9
Large farm/small farm yields (all cereals 1987)	0.9	1.1	2.9	-	3.1

Source: Yields (rows 1 and 2) and irrigated area (row 5), FAO (1987, 1991).

Large/small farm yield ratios (row 7): India: Singh (1990).
Fertiliser price/maize price ratio (row 6): Lele et al., (1989).
Percentage of farmers receiving institutional loans (row 3): NABARD and Table 12.3.
MV/TV yield ratio (row 4): Singh (1990).

[18] For these two cases, see respectively Singh (1990) and Booth (1990).

APPENDIX 1: THE RAW DATA AND THEIR DERIVATION

This Appendix presents the raw data used to compile the tables and statistical analysis of Section III and lists their sources. It then, in respect of crop yields only, presents an extended discussion of the methods which have been used to estimate crop yields in Kenya, Malawi and Zimbabwe during the period under review.

In all three countries the estimation of *ex post* yields forms part of a continuous forecasting and estimation cycle.

Kenya

Maize production statistics are computed separately for 'large farms' (formerly farms under European ownership, now farms more than 5 hectares in area) and 'small farms' (others). In 1992, 4,097 farms were classified as 'large' and accounted for about 45 per cent of the agricultural land area. Owners of large farms are sent an annual questionnaire in which they are asked to state production and sales of each crop for the previous crop year and area planted to each crop for the coming year. The response rate for 1991-92 was about 90 per cent, and this figure has not varied greatly over the previous ten years (personal communication, J.B. Kirimi, Kenya Central Bureau of Statistics). Farmers' statements of maize and other grains sold off-farm can be cross-checked against measured deliveries to the National Cereals and Produce Marketing Board (NCPB) which until recently was the only legal buyer of maize in bulk; but there has always been a substantial black market in maize, and since 1990 farmers have been authorised to sell maize in any quantity to non-NCPB traders, thus depriving such checks of whatever validity they used to have.

For the small farm areas, there are three sources of statistics:

1. *The Ministry of Agriculture* which collects crop estimates through its extension staff. The estimates are made in consultation with a 10 per cent sample of farmers in each district, known as 'contact' farmers, which is intended to be representative of the spectrum of technologies and farming competence within that district. Crops are not cut; rather, farmers are asked to state whether their yields are up or down from the previous year, and by what percentage. Thus everything depends on the accuracy of the base, which appears to be a guesstimate agreed between the farmer and the extension officer.

2. *The Central Bureau of Statistics*, which has collected data through its own survey unit since 1980. Within every district 24 clusters of 100-150 households are selected; within every cluster a 10 per cent sample is taken. This sample is interviewed four times a year: in January, to determine the harvest expected for the 'short rains' crops (October to December) and to confirm the harvest achieved for the long rains crops (March to May); in March, to

determine areas under long rains crops; in July-August, to make a forecast of the long rains harvest and to confirm the short rains crops; and in October-November, to assess the area planted to short rain crops. For the *ex post* estimate, however, the farmer's estimate is taken; no crop cuts are made.

3. *The Kenya Rangeland Ecological Monitoring Unit (KREMU)* which uses aerial photographs to assess the area under cereal crops. The photographs are taken when a crop is about half a metre tall. A radiometer is used to estimate the production of green biomass, using a radiometer to assess the reflectance ratio of the near infra-red band (800 nm) and the red band (670 nm) from the crop (Ottichilo and Sinange, 1990). Although this is the most 'scientific' of the techniques used in Kenya, it can only estimate the yield of maize in the field; it is therefore unable to make any correction for the percentage of the crop harvested or for post-harvest losses.

These forecasts are not produced in isolation; there are quarterly meetings involving all the three parties mentioned and the NCPB, following which all parties are free to - and often do - change their prior estimates.

The estimates published by FAO are set out in Table A-1. FAO generally has a tendency to lean towards the CBS estimates which are generally lower than those produced by the Ministry of Agriculture. One systematic reason for this is that the Ministry of Agriculture corrects for intercropping, whereas the CBS does not: thus, a hectare of maize interplanted half and half with beans which yields a ton of maize is determined to yield 1 ton/ha by the CBS, and 2 tons/ha by the Ministry of Agriculture. Finally, the KREMU estimates cannot be taken into account, since they measure the crop standing in the field rather than the harvested crop; but if the KREMU crop forecast made in July is closer to the Ministry of Agriculture than to the CBS estimate it has been common for the FAO to lean towards the Ministry of Agriculture rather than the CBS estimate when it later comes to record *ex post* yield.

Malawi

Malawi - where maize and other grains are predominantly small-farm rather than estate crops - is distinguished from the other two countries examined here as only having one official source of grain yield statistics, namely the Ministry of Agriculture. Under the 'traditional method' which applies to all statistics published for years up to and including 1988, the managers of the eight Agricultural Development Divisions (ADD's) make forecasts, and subsequently estimates of crop areas and yields on the basis of estimates made by field extension staff. The method is the same as that used by the Ministry of Agriculture in Kenya: the farmer is asked by the extension agent whether the yield he achieved was higher or lower than that achieved in the previous year, and by how much. The sampling fraction used by field staff has not, under this traditional method, been laid down from above, and varies from one ADD to another; on the basis of interviews in individual ADD's, I estimate the range of variation as being from 5 to 10 per cent.

More recently, the Government of Malawi has made attempts to improve the accuracy of maize yield data. These are of two types:

(i) An agrometeorologist (funded by FAO) now makes a forecast from rainfall statistics, in April every year at the end of the rainy season, of what yields will be in individual regions. The *ex post* crop estimate is now corrected by the Ministry of Agriculture if it is too far out of line with this forecast.

(ii) In four regions (Salima and Blantyre ADD's since 1989, and Kasungu and Mzuzu ADD's since 1991) sampling is now random, and the crop is actually weighed. The formal procedure is the following: blocks of 120 farms to be sampled are chosen randomly within the ADD at a sampling faction of 1:5. Within selected blocks a sample of forty families is selected. For each such family, in June, the crop is measured, also by sampling, i.e., the crop is delivered in baskets or carts, and the extension officer weighs the contents of one cart-load and multiplies by the number of cart-loads which the farmer declares to make an estimate of the crop. This process is to be extended to all ADD's in the 1993/4 cropping season.

In making its published estimate the FAO therefore is relying on just one estimate, which however is produced by 'objective' methods for about half the country and by 'subjective' methods for the other half. In those parts of the country for which estimates are still 'subjective' the FAO sometimes applies its own correction to the Ministry of Agriculture data in response to information coming from weather records.

Zimbabwe

The system of data collection in many ways parallels that used in Kenya with one or two additional complications. Crop yield data are compiled separately for four different groups of farmers: 'large scale commercial farmers' occupying land bought from large scale commercial farmers in what were formerly African Purchase Areas, settlement schemes and communal areas. For the first two groups, crop yield data are obtained from a questionnaire filled in by the farmer. The response rate to the questionnaire for larger commercial farmers is higher than that for small-scale commercial farmers; the figures in the 1990-91 crop year (1991-92 being an exceptional year because of severe drought) were 95 and 82 per cent respectively.

For settlement schemes and communal areas, there are two sources of data: the National Household Agriculture and Livestock Survey mounted by the Central Bureau of

Statistics (CBS) and the field returns provided by the extension staff of the Department of Agricultural, Technical and Extension Services (AGRITEX) of the Ministry of Agriculture. The CBS uses cluster sampling methods with a sampling fraction within each cluster of about 5 per cent. AGRITEX extension staff (of which there are, on average, one to every 800 farmers) make eye estimates of the size of the crop as it stands in the field. These are corrected by weighing a sample of the crop post-harvest. For the last eight years AGRITEX staff have been advised by FAO statisticians, who further correct the AGRITEX returns in the light of rainfall and temperature data. Both AGRITEX and the CBS come with their separate estimates to regular meetings of the National Crop Forecasting Committee, which determines an 'official' *ex post* estimate of the size of grain crops by sector (i.e., large scale commercial, small-scale commercial, settlement and communal). This is the figure subsequently published in the FAO *Production Yearbook.*

A more detailed breakdown of crop yields by district in communal areas, which serves as an additional check on the data produced by CBS and AGRITEX, has been provided since 1988-89 only by the Farm Management Research Sector of the Ministry of Agriculture. This takes nine survey sites evenly spread across each of the five agro-climatic regions of the country and samples sixty households in each area, making an assessment of the 'production function for each crop in each sample household. At an aggregate level the results for maize and sorghum are broadly consistent with those published by the FAO as represented in the following table:

ZIMBABWE COMMUNAL AREAS: REPORTED CROP YIELDS (KG/HA), 1989-90

	Maize	*Sorghum*	*Millets*
Crop Forecasting Committee Figure for Communal Areas (used as basis for FAO published figure)	1289.4	189.4	217.2
Weighted average 'all areas' from Ministry of Agriculture Farm Management Survey	1324.6	170.7	254.0

Source: GRZ (1992), Table 4.1, 4.6, 4.7

However, at present there is no formal attempt to incorporate data from the Ministry of Agriculture farm management survey - at present our most accurate source of information on the communal areas - into national crop production statistics.

Table A-1: KENYA, ZIMBABWE AND MALAWI: MAIZE AND SMALL GRAIN YIELDS 1960-91 (tons/hectare)

YEAR	KENYA		MALAWI		ZIMBABWE	
	MAIZE	SORGHUM	MAIZE	SORGHUM	MAIZE	SORGHUM
1960	[_1.31_]	_0.00_	_0.00_	_0.00_	[_1.97_]	_0.00_
1961	[_1.34_]	_0.00_	_0.00_	_0.00_	[_3.28_]	[_0.92_]
1962	[_1.36_]	_0.00_	_0.88_	_0.00_	_1.42_	_0.21_
1963	1.57	_0.91_	_0.90_	_0.53_	_1.10_	_0.70_
1964	1.71	_0.00_	_1.12_	_0.00_	_1.08_	_0.86_
1965	1.64	_0.00_	_1.13_	_0.00_	_1.13_	_0.64_
1966	1.41	_0.00_	_1.14_	_0.00_	_1.33_	_0.72_
1967	1.79	_0.00_	_1.47_	_0.00_	[_2.50_]	_0.77_*
1968	1.97	_0.00_	_1.02_	_0.00_	[_2.38_]	_0.79_*
1969	2.10	_0.00_	_1.08_	_0.00_	[_2.49_]	_0.79_*
1970	1.49	_0.00_	_0.90_	_0.00_	1.20	_0.71_*
1971	2.11	_0.00_	_1.05_	_0.47_	1.90	_0.71_
1972	1.73	_0.00_	_1.04_	_0.47_	2.31	_0.71_
1973	1.66	_0.00_	_1.04_	_0.47_	1.21	_0.71_
1974	1.85	_0.00_	_1.15_	_0.25_	2.03	_0.63_
1975	2.17	_0.00_	_1.00_	_0.68_	1.75	_0.71_
1976	2.04	_0.00_	_1.09_	_0.76_	1.81	_0.71_
1977	2.07	_0.64_	_1.05_	_0.44_	1.86	_0.71_
1978	1.98	_0.64_	_0.94_	_0.44_	1.67	_0.71_
1979	1.70	_0.65_	_1.00_	_0.44_	1.01	_0.57_
1980	1.58	_1.05_	1.13	_0.92_	1.32	_0.58_
1981	2.07	_1.05_	1.17	_1.08_	2.07	_0.57_
1982	1.89	_1.05_	_1.17_	_1.11_	1.27	_0.60_
1983	1.77	0.18	_1.19_	0.30	0.68	_0.18_
1984	1.25	1.23	_1.18_	0.67	0.83	_0.33_
1985	1.95	0.51	_1.08_	0.67	2.15	_0.57_
1986	2.41	0.44	_1.02_	0.64	1.93	_0.26_
1987	2.01	0.51	1.17	0.47	0.78	_0.48_
1988	2.24	0.51	1.18	0.72	1.73	0.80
1989	2.17	0.41	1.00	0.67	1.61	0.51
1990	2.03	1.03	1.14	0.50	1.73	0.66
1991	_2.22_			0.60		

Sources: Italic = FAO Production Yearbook
Other = Central Bureau of Statistics for countries named

Notes: * Millet and Sorghum combined [ ] Estate Yields only

Table A-2: DATA MATRIX: KENYA

Year	Maize yield (tons/ha)	Maize Price (sh/ton)	Fertiliser Price (sulphate of ammonia; (£/ ton)	Index of agricultural labour costs (K £ pa)	Weather (rainfall in mms)	Ratio of hybrid to local maize yields (research stations)	Credit disbursements (1) Total lending to small farmers by AFC and co-operative credit societies (K£mn)	(2)Total value of agricultural credit (K£' mn) granted by commercial banks
1960	1.31	320	261		1081	1.9	-	
1961	1.34	355	290	44	677	1.5	-	
1962	1.36	355	288	48	1117	1.7	-	
1963	1.57	240	279	47	699	1.4	-	
1964	1.71	328	282	62	498	2.1	-	
1965	1.64	362	310	65	519	1.8	2.5	
1966	1.41	355	357	69	512	1.3	0.9	6.3
1967	1.79	401	290	68	982	1.6	2.4	6.6
1968	1.97	352	262	71	460	2.4	2.6	7.8
1969	2.1	307	343	73	584	2.6	3.2	8.6
1970	1.49	307	361			1.8	1.5	
1971	2.11	275	344	79	403	2.6	3.1	12.5
1972	1.73	333	434	94	691	1.8	1.6	12.1
1973	1.66	388		93	362	2.6	1.9	17.8
1974	1.85	388	1108	96	433	1.6	4.0	20.4
1975	2.17	464	1785	182	938	0.9	12.1	40.6
1976	2.04	697		283	1042	1.2	18.0	54.3
1977	2.07	765	877	291	900	2.8	12.0	72.5
1978	1.98	888	919	326	510	2.9	13.6	89.9
1979	1.70	774	1403	340	595	2.9	13.2	102.3
1980	1.58	888	1194	260	731	2.1	17.8	110.5
1981	2.07	953	1794	289	735	1.9	13.2	110.5
1982	1.89	1000	1842	301	460	2.3	8.0	112.8
1983	1.77	1070	2450	323	465	2.7	10.6	138.4
1984	1.25	1540	1969			1.9	15.9	136.4
1985	1.95	1750	1725	331		1.6	26.1	148.3
1986	2.41	1870	2320	373	334	1.3	37.5	147.1
1987	2.01	1980	1691		794	2.3	29.9	204.7
1988	2.24	2090		463	731	2.9	33.4	256.0
1989	2.17	2142		510	971	2.6	32.6	291.7
1990	2.03	2233		570		3.0	31.8	
1991	2.22	2616		647		2.4		

Sources: **Maize yields**: Central Bureau of Statistics, Agricultural Surveys Division (for further details, see Appendix 1).

Fertiliser prices: CIF landed cost of sulphate of ammonia as recorded in Kenya, *Annual Abstract of Statistics*, Tables 67 and 71.

Maize prices: prior to 1964, Mosley (1983) Table 3.6; thereafter Kenya, *Economic Surveys*, various.

Credit disbursements: (1) total turnover of agricultural savings and credit societies, and 'loans to small farmers' from Kenya, *Statistical Abstracts*, various (eg. 1991, Table 137).

(2) Loans by commercial banks to agricultural enterprises, from Kenya, *Statistical Abstracts*, various.

Weather: Total annual rainfall at Katumani Agricultural Research Station for calendar year (source: KARI).

Agricultural wage rates: Kenya, *Annual Abstract of Statistics*, Table 188.

Ratio of hybrid to local maize yields: data kindly supplied by National Agricultural Research Station Kitale. Ratio quoted is yield of appropriately fertilised hybrid maize as a multiple of yield from appropriately fertilised local maize.

Table A-3: DATA MATRIX: MALAWI

Year	Yield (maize) tons/ha	Maize Price (t/kg)	Fertiliser Price (K/bag)	Index of agricultural labour costs (K/month)	Weather (rainfall in mms)	Credit disbursements (1) Value of loans to smallholders by Smallholder Agricultural Credit Administration	Credit disbursements (2) Commercial banks advances to agricultural sector (K/million)
1960	"		1.56				85
1961	"		1.65			-	97
1962	0.88		1.47			-	112
1963	0.90		1.39			-	131
1964	1.12	0.97	1.72	7.3		-	136
1965	1.13	0.93	1.78	7.5		-	144
1966	1.14	0.98	1.96	8.0		-	119
1967	1.47	1.00	1.89	8.3		-	155
1968	1.02	1.06	2.01	8.5		-	184
1969	1.08	1.38	2.14	8.1		-	187
1970	0.90	1.65	2.20	8.8		8	208
1971	1.05	1.96	2.75	9 2		14	254
1972	1.04	2.34	2.75	9.5		17	261
1973	1.04	2.68	2.75	9.6		21	289
1974	1.04	3.00	2.75	10.8		32	250
1975	1.15	4.00	6.70	10.6		25	278
1976	1.00	5.00	5.50	11.2		31	301
1977	1.09	5.00	5.50	12.3		36	537
1978	1.05	5.00	5.50	14.4		43	818
1979	0.94	5.00	5.50	14.5		52	926
1980	1.00	6.60	5.50	15.9	1073	78	942
1981	1.13	6.60	6.50	18.8	1017	93	1151
1982	1.17	6.60	9.00	24.7	894	122	1385
1983	1.17	11.00	10.50	22.1	885	156	1134
1984	1.19	11.00	12.00	23.7	974	180	1178
1985	1.18	12.20	13.50	26.4	1187	211	1320
1986	1.08	12.20	17.50	26.4	1180	207	1436
1987	1.02	12.20	18.00	29.0	944	203	1335
1988	1.17	16.60	23.00	30.5	1123	243	1399
1989	1.18	24.00	17.00	33.1	1245	301	1565
1990	1.00	26.00	33.00	39.1	1030	315	1890
1991	1.14		38.00		989	333	

Sources: **Maize yields, fertiliser prices, maize prices**: *Malawi Agricultural Statistics*: 1991 *Annual Bulletin*, Ministry of Agriculture, 1992. For period before 1970, maize yields are from *FAO Production Yearbook*; prices are unit value indices taken from *Monthly Bulletin of Key Economic Indicators*, 25th August 1969.

Credit disbursements: (Col. 1) Smallholder Agricultural Credit Administration *Annual Reports*, various. (Col. 2) Malawi, *Statistical Yearbook*, 1992, Table 14.6 and equivalent.

Agricultural Labour Costs: *Malawi Monthly Statistical Bulletin*, Table 8B.

Weather: Average rainfall for all Agricultural Development Divisions; data supplied by Malawi Meteorological Office, Blantyre.

Ratio of hybrid to local maize yields: *Malawi Agricultural Statistics*, 1991, Annual Bulletin supplemented by data kindly supplied by National Agricultural Research Station, Chitedze.

Table A-4: Data Matrix: Zimbabwe

Year	Yield (maize) (tons/ha)	Maize Price ($/ton)	Fertiliser Price ($/ton ex Harare)	Ratio of hybrid to local maize yields	Weather rainfall in mm	Agricultural labour costs ($ per month)	Sorghum Price ($/ton)	Credit disbursements	
								(1) AFC disbursements to smallholders ($m)	(2) Total lending to agricultural sector by commercial banks ($m)
1960		39.68		3.4		7.0	41.21	-	
1961		34.72		3.6		7.1	41.21	-	
1962	1.42	26.07		3.7		7.0	37.45	-	
1963	1.1	29.57		3.2		7.5	32.78	2	
1964	1.08	40.85		2.9		7.9	29.90	6	
1965	1.13	39.09		2.9		8.0	32.32	9	49
1966	1.33	37.70		3.4		8.1	34.43	10	44
1967		31.21		3.8		8.4	28.66	11	43
1968		29.13		3.2		9.6	32.88	11	50
1969		33.45		3.3		10.2	35.16	11	53
1970	1.20	32.97		3.4		10.5	35.53	12	59
1971	1.90	30.05		4.0		10.9	37.25	13	73
1972	2.31	25.88	63.20	6.1		11.2	38.64	15	73
1973	1.21	36.37	63.20	4.6			41.65	14	80
1974	2.03	40.11	63.20	5.7	1003		41.81	18	98
1975	1.75	37.00	74.20	4.6	819	17	41.54	26	111
1976	1.81	44.00	127.40	5.2	736	19	41.54	30	121
1977	1.86	52.00	116.40	5.4	748	21	60.00	36	117
1978	1.67	53.00	129.40	4.9	980	23	75.00	33	124
1979	1.01	60.50	138.80	3.0	569	25	75.00	39	128
1980	1.32	85.00	141.60	3.3	640	32	80.00	61	164
1981	2.07	120.00	168.20	5.5	860	53	105.00	61	179
1982	1.27	120.00	187.20	3.7	439	71	115.00	84	229
1983	0.68	120.00	106.80	2.5	403	80	115.00	122	
1984	0.83	140.00	106.80	2.6	464	80	120.00	136	
1985	2.15	180.00	347.21	5.5	746	90	140.00	148	370
1986	1.93	180.00	406.00	4.9	685	102	180.00	167	440
1987	0.78	180.00	406.00	3.1	422	125		210	792
1988	1.73			4.1	743			248	658
1989	1.61			4.2				295	750
1990	1.73			3.0					
1991				3.9					

Sources: **Maize yields**: Central Statistical Office, *Quarterly Digest of Statistics*, various issues.
Maize and sorghum prices: Agricultural Marketing Authority, personal communication.
Fertiliser prices: Rohrbach (1989), complemented by *Economic Review of the Agricultural Industry of Zimbabwe* (1985), updated from the AMA direct. Prices quoted are for Grade A maize ex GMB depot.
Weather: National average annual rainfall, from Zimbabwe, *Statistical Yearbook 1989*, Table 1.3, and other years.
Credit disbursements: (1) smallholder credit disbursed by Agricultural Finance Corporation (numbers of loans); source Agricultural Finance Corporation *Annual Reports*. (2) Short-term credit to farmers from commercial banks: *Zimbabwe Statistical Yearbook* (various issues, eg. 1989, Table 14.4).
Agricultural wage rates: *Zimbabwe Statistical Yearbook, 1989*, Table 4.9; Economic Survey of Rhodesia 1969, Table 13 (conversion rate of £1 = $1.5 is assumed for period prior to 1970).

Table A-5: HYBRID SEED AND FERTILISER CONSUMPTION

	(Smallholders only) ZIMBABWE		MALAWI		KENYA	
Year	Fertiliser (MT)	Seed (MT)	Fertiliser (MT)	Seed (HA)	Fertiliser (K £ million)	Seed (MT)
1960			166			
1961			224			
1962			414			100
1963			1018			800
1964			1995			1000
1965			1596			2000
1966			8586		2.0	1800
1967			9828		1.6	2000
1968			9905		1.8	2400
1969			15559		2.3	4600
1970			20725		3.0	6100
1971			24831			6500
1972			24054			6800
1973			31743			8100
1974			14810			10800
1975	24000	2350	22353			12200
1976	19000	3950	30471			11500
1977	20000	2700	44355			9300
1978	25000	3700	43939			12100
1979	25000	4250	43847			12000
1980	27000	4300	49142			12800
1981	90000	9650	57200			12900
1982	96000	13950	41738		14.68	15000
1983	98000	16900	63251		14.34	18500
1984	106000	17300	65786	89005	21.12	19500
1985	127664	19500	84781	74935	32.94	21800
1986	130000E	20210E	64736	68590	34.08	
1987			81807	37095	38.96	
1988			94469	66900	49.18	
1989			111879	85385	69.41	
1990			102204	135023	33.28	
1991			104436	179358	62.63	

Sources: Zimbabwe: Rohrbach (1989); Kenya: Karanja (1990), Table 2; Malawi Ministry of Agriculture (1991).

APPENDIX 2: **THE 'CREDIT SUBMODEL'**

On pages 7-10 of the text, we have presented reasons for believing that the conditions on which credit is made available to African farmers constitutes an important determinant of their adoption of modern varieties and hence of their crop yields. Our first approach to embodying this idea into the analysis consisted of simply incorporating the volume of formal-sector credit into the production function for modern varieties, which was therefore specified as:

$$Y_m = P_o g(N, L, Z, C, W) \tag{2b}$$

However, the effects of credit on the adoption of modern varieties may be more complex than a simple monotonic relationship connecting aggregate credit volumes to crop output. Other dimensions of the farmer's access to credit (eg. price) may also be important, as may the interactions between different suppliers in the credit market. This appendix considers these possibilities.

We begin from Figure 2, in which a relationship is postulated between the supply of credit and the quantity of modern inputs purchased. As the figure is drawn, the supply and price of credit are determined by a 'quantity closure', i.e., the rate of interest is set by a legal authority below the market-clearing rate. If the price of credit is allowed to rise to a market-clearing rate (eg., OK in figure 2(a)), demand as well as supply considerations will exert an influence on interest rates, and thence on the purchase of modern inputs. The demand curve for credit in the left-hand part of Figure 2 is assumed to be determined by the marginal efficiency of capital, on other words, the rate of return to be expected from the modern inputs listed on the vertical axis. The position of the supply curve is determined by the costs of supplying credit, which are interlinked by the relationship (Mosley and Dahal 1987; Anderson and Khambata 1985):

$$r^* = \frac{i + a}{1 - p}$$

where r^* = 'break even' charge for credit

i = cost of borrowing money

a = administrative costs associated with lending money

p = probability of non-repayment of loan

The position of the supply curve, for any given level of lending, is assumed to be delivered by the break-even charge r*; as the transaction costs represented by a and p decline over time, the supply curve and the 'equilibrium interest rate' move downwards.

It remains, importantly, to ask by what agency the credit depicted in Figure 2a is supplied. As noted in the main text (page 9) rural capital markets in most developing countries are segmented into three parts:

(i) commercial banks who lend only to large and not to small farmers;

(ii) agricultural development banks and other 'quasi-formal' operations financed by some combination of government, NGO and external aid agency, and

(iii) informal moneylenders.

By implication, the lender in the left-hand quadrant of Figure 2 is assumed to be a 'quasi-formal' operation. But what will the inter-relationship be between this part of the credit market and the others?

Let us, for the moment, focus on the connection between the two parts of the credit market that affect smallholder grain producers - the 'quasi-formal' operations (sector (ii)) and the informal moneylender (sector (iii)). The simplest assumption would be that of simple substitution; as the 'quasi-formal' sector expands, so it takes away business from the informal sector, which therefore contracts. Such has indeed been the explicit intention of many 'quasi-formal' programmes, including the entire co-operative movement in India[19]. However, reality may be more complex:

(i) Moneylenders and 'quasi-formal' lenders may be serving different markets; in particular, money lenders may be unwilling to lend long term or to individuals from outside their

19 "The whole object of creating a structure of rural co-operatives is to provide a positive institutional alternative to the moneylender himself, something which will compete with him, remove from the forefront and put him in his place" (Reserve Bank of India, 1954, Vol. 2, p. 481-482).

village whom they do not know, hence 'quasi-formal' lenders may be tapping new markets and thus expanding the aggregate volume of credit available.

(ii) There may be income as well as substitution effects to take into account; for example, those who successfully borrow from 'quasi-formal' institutions may experience an increase in income, part of which is then used to borrow from moneylenders for specific purposes and thus expand their aggregate volume of business.

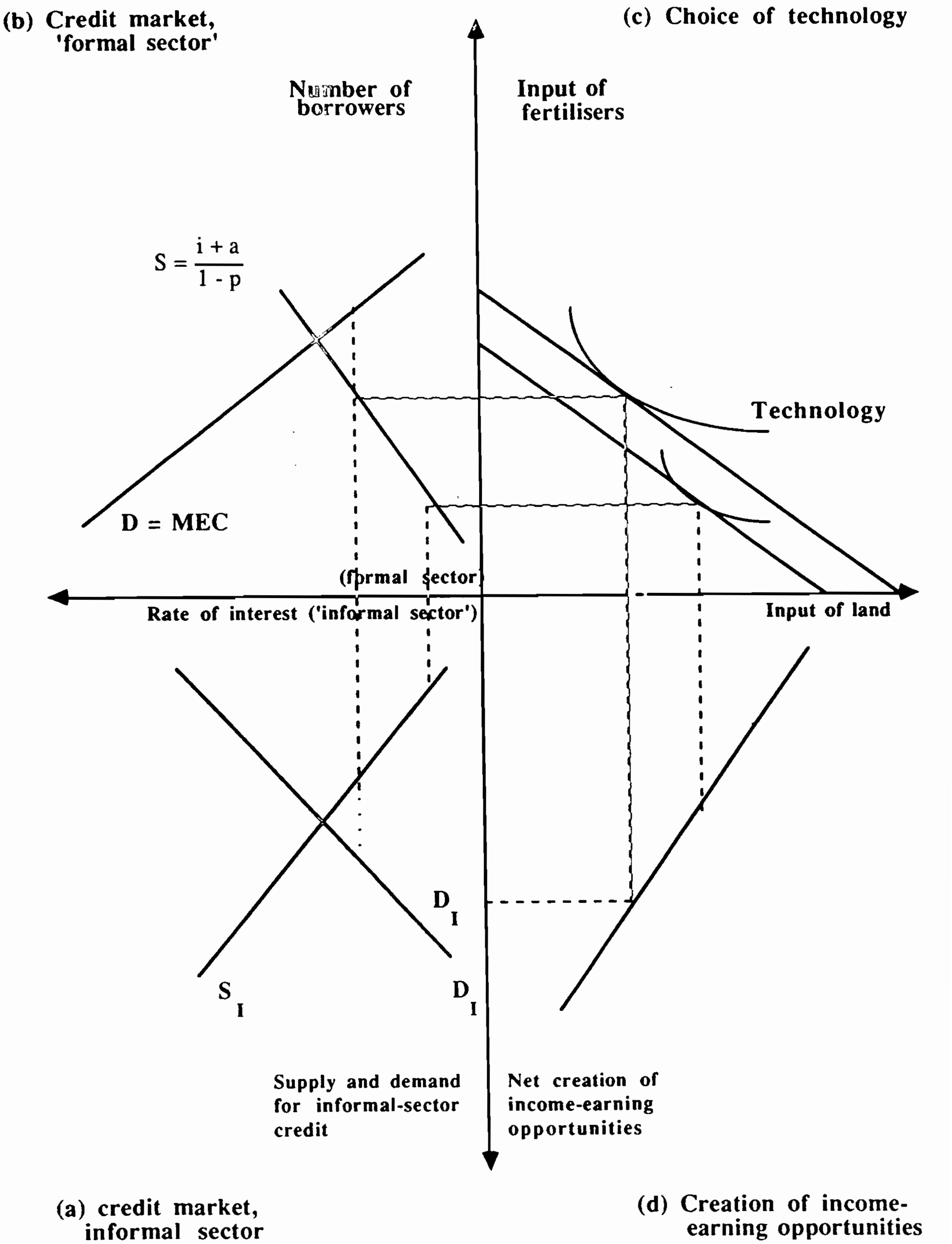
For these reasons we postulate a link not between *interest rates* prevailing in the formal and the informal markets, but between *conditions of access* prevailing in the formal and informal markets. This is done in Figure 3, the upper two quadrants of which are identical to Figure 2. If conditions in the informal market tighten, (in other words, the possibility that a borrower with given characteristics will obtain credit from a moneylender diminishes), the demand for 'formal' sector credit (i.e., the marginal efficiency of capital schedule) moves outwards. By the same token, if conditions in the 'quasi-formal' credit market tighten the demand curve for informal credit will shift in an outward, i.e., south-westerly, direction. The third quadrant of the diagram remains unaltered.

From the above discussion we deduce the following propositions for empirical testing:

[1] Consumption of 'green revolution' inputs, and hence yields, may depend on the price (interest rate) of credit made available by the formal sector as well as its volume.

[2] Consumption of 'green revolution' inputs, and hence crop yields, may depend on the **total** volume of credit made available for the formal and informal sectors, and not on what is made available by the formal sector alone.

Figure 3: INTERLINKAGE BETWEEN CREDIT MARKET, CHOICE OF AGRICULTURAL TECHNOLOGY AND INCOME-EARNING OPPORTUNITIES



[3] However, no simple relationship can be deduced between access to credit in the formal and informal sector, since the analytical linkage goes from supply in one market to demand in the other, and if markets are cleared by quantity rationing rather than by price closure, gaps between supply and demand may persist over time. If, *and only if*, they are cleared by price closure, a price reduction in one market will cause price reductions and quantity increases in the other.

The first of these hypotheses is considered empirically in the analysis of Table 8(a) to 8(c) above, and the last is considered in Table 10 above.

BIBLIOGRAPHY

Allan, W. (1965), *The African Husbandman*. Edinburgh: Oliver and Boyd.

Alexandratos, N. (1991), "World Agriculture in the Next Century: Challenges for Production and Distribution". Paper presented to the "XXI International Conference of Agricultural Economists", Tokyo, August. Rome: Food and Agriculture Organization.

Anderson, D., and F. Khambata (1985), "The Merits and Limitations of Commercial Interest Rate Policies in Developing Countries". *Economic Development and Cultural Change*, Vol. 35.

Bates, R. (1981), *Markets and States in Tropical Africa*. Berkeley: University of California Press.

Biswanger, H., and P. Pingali (1989), "Induced Technical and Institutional Change in African Agriculture". *Journal of International Development*, 1, January.

Biswanger, H.P., and D. Sillers (1983), "Risk Aversion and Credit Constraints in Farmers' Decision-making: A Reinterpretation". *Journal of Development Studies*, Vol. 19, no. 12.

Booth, A. "Agricultural Growth in Indonesia and its Implications for other Developing Countries". *World Development*, Vol. 17.

Boserup, E. (1965), *The Conditions of Agricultural Growth: The Economics of Agrarian Change Under Population Pressure*. London: Allen and Unwin.

Bratton, M. (1986), "Financing Smallholder Production: A Comparison of Individual and Group Schemes in Zimbabwe". *Public Administration and Development*, Vol. 6.

Chimedza, R. (1990), "Zimbabwe's Informal Financial Sector: An Overview". *Working Paper*, AEE 4/90. Harare: University of Zimbabwe, Department of Agricultural Economics and Extension.

Chipeta, C., and M.L.C. Mkandawire (1992), "The Informal Financial Sector in Malawi". *African Review of Money, Finance and Banking*, Vol. 2.

Collinson, M. (1989), "Small Farmers and Technology in Eastern and Southern Africa". *Journal of International Development*, 1.

Conroy, A. (1992), "The Economics of Smallholder Maize Production in Malawi with Reference to the Market for Seed and Fertiliser". Unpublished PhD thesis, IDPM, University of Manchester.

de Janvry, A., M. Fafchamps, and E. Sadoulet (1991), "Peasant Household Behaviour with Missing Markets: Some Paradoxes Explained". *Economic Journal*, Vol. 101.

de Janvry, A., and E. Sadoulet (1992), "Structural Adjustment under Transactions Costs". Paper prepared for the Conference of European Association of Agricultural Economists, Hohenheim, Germany, September.

Ellis, F. (1988), *Peasant Economics: Farm Households and Agrarian Development*. Cambridge: Cambridge University Press.

FAO (1987), *FAO Production Yearbook 1986*. Rome: Food and Agriculture Organization.

________ (1991), *FAO Production Yearbook 1990*. Rome: Food and Agriculture Organization.

________ (1992), *FAO Production Yearbook 1991*. Rome: Food and Agriculture Organization.

Feder, G., R. Just, and D. Zilberman (1985), "Adoption of Agricultural Innovations in Developing Countries: A Survey". *Economic Development and Cultural Change*, Vol. 33.

Gibbon, D., H. Rees Jones, and J.C.H. Morris (1980), *Kitale Agricultural Research Station, Kenya 1972-78: Evaluation Report*. London: Overseas Development Administration Evaluation Unit.

Government of Kenya (GOK) (1991), *Statistical Abstracts*. Nairobi: Government Printers.

Government of the Republic of Zimbabwe (GRZ) (1989), *Statistical Yearbook 1989*. Harare: Government Printer.

_______ (1992), *Second Annual Report of Farm Management Data for Communal Area Farm Units*. Harare: Ministry of Lands, Agriculture and Rural Resettlement, Farm Management Research Section.

Harrigan, J. (1991), "Malawi", in P. Mosley, J. Harrigan, and J. Toye, (1991) *Aid and Power*, 2 Volumes. London: Routledge.

Harrison, P. (1987), *The Greening of Africa: Breaking Through in the Battle for Land and Food*. London: Paladin.

Hulme, D. (1990), "Can the Grameen Bank be Replicated? Recent Experiments in Malaysia, Malawi and Sri Lanka", *Development Policy Review*, Vol. 8.

Idachaba, F. (1991), "Policy Options for African Agriculture", in J. Dreze, and A. Sen (eds.) (1991) *The Political Economy of Hunger*, Vol. 3. Oxford: Oxford University Press.

Karanja, D.D. (1990), *The Impact of Research on Maize Yields in Kenya 1955-1988*. Nairobi: Kenya Agricultural Research Institute.

Kydd, J. (1989), "Maize Research in Malawi: Lessons from Failure". *Journal of International Development*, 1.

Lele, U., and A. Goldsmith (1989), "The Development of National Research Capacity: India's Experience with the Rockefeller Foundation and its Significance for Africa". *Economic Development and Cultural Change*, Vol. 37.

Lele, U., and R. Meyers (1989) "Growth and Structural Change in East Africa: Domestic Policies, Agricultural Performance and World Bank Assistance, 1963-86". *World Bank MADIA Discussion Paper*, No. 3.

Lele, U., R. Christiansen, and K. Kadiresan (1989), "Fertiliser Policy in Africa: Lessons from Development Programmes and Adjustment Lending 1970-87". *World Bank MADIA Discussion Paper*, No. 5.

Lipton, M. (1988), "The Place of Agricultural Research in the Development of sub-Saharan Africa". *World Development*, Vol. 16.

Lipton, M. (1990), "Requiem for Adjustment Lending?". *Development Policy Review*, Vol. 8.

Matlon, P.J. (1990), "Improving Productivity in Sorghum and Pearl Millet in Semi-arid Africa". *Food Research Institute Studies*, Vol. 22.

Mellor, J., C. Delgado, and M.J. Blackie (eds.) (1987), *Accelerating Food Production in Sub-Saharan Africa*. Baltimore: John Hopkins University Press.

Mosley, P. (1983), *The Settler Economies: Studies in the Economic History of Kenya and Southern Rhodesia 1900-1963*. Cambridge: Cambridge University Press.

_______ (1986), "Agricultural Performance in Kenya since 1970: Has the World Bank Got it Right?" *Development and Change*, Vol. 17.

Mosley, P., and R.P. Dahal (1987), "Credit for the Rural Poor: A Comparison of Policy Experiments in Nepal and Bangladesh". *Manchester Papers on Development*, 3.

Nadar, H.M., and W.A. Faught (1984), "Maize Yield Response to Different Levels of Nitrogen and Phosphorous Fertiliser Application". *East African Agriculture and Forestry Journal*, Vol. 44.

Norman, D., H. Sigwele, and D. Baker (1987), "Reflections on Two Decades of Research on Sorghum-based Farming Systems in Northern Nigeria and Botswana". Paper presented at the Conference on "Food Security Research in Southern Africa", Harare.

Osmanzai, M. (1991), "Cereals Agronomy Research 1989/90" in *Proceedings of the Seventh Regional Workshop on Sorghum and Millets for Southern Africa*. Bulawayo: SADCC/ICRISAT.

Ottichilo, W.K., and R.K. Sinange (1990), *Long Range Maize and Wheat Production Trends in Kenya for 1985-89*. Kenya Government: Department of Resource Surveys and Remote Sensing.

Reserve Bank of India (1954), *All-India Rural Credit Survey*, Vol. 1; *The Survey Report*, Vol. 2; *The General Report*, Vol. 3; *The Technical Report*. Bombay: Reserve Bank of India.

Rohrbach, D. (1989), "The Economics of Smallholder Maize Production in Zimbabwe: Implications for Food Security". *MSU International Development Paper*, No. 11. East Lansing: Michigan State University and Harare: University of Zimbabwe, Department of Agricultural Economics and Extension.

_______ (1990), "Strengthening Sorghum and Millet Production and Marketing on the SADCC Region". Paper prepared for the "Small Grains Workshop", MLARR-Zimbabwe and CIDA, March.

Rohrbach, D., J. Stack, B. Hedden-Dunkhorst, and J. Govereh (1990), "Agricultural Growth and National Food Security", in T.S. Jayne, M. Rukuni, and J.B. Wycoff (eds.) (1990), *Integrating Food and Nutrition Policy in Zimbabwe*. Harare: University of Zimbabwe.

Ruttan, V.W., and C. Thirtle (1989), "Induced Technical and Institutional Change in African Agriculture". *Journal of International Development*, 1.

Singh, I. (1990), *The Great Ascent: The Rural Poor in South Asia*. Baltimore: John Hopkins University Press.

Smale, M. *et al.* (1991), "Chimanga cha Makolo, Hybrids and Composites: An Analysis of Farmers' Adoption of Maize Technology in Malawi 1989-91". *CIMMYT Economics Working Paper*, 91/04. Mexico, D.F.: CIMMYT.

Stiglitz, J., and A. Weiss (1981), "Credit Rationing in Markets with Imperfect Information", *American Economic Review*, Vol. 71.

Thirtle, C. *et al.* (1993), "Agricultural Productivity in Zimbabwe 1970-1990". *Economic Journal*, Vol. 103.

Timothy, D.H., P.H. Harvey, and C.R. Dowswell (1988), *Development and Spread of Improved Maize Varieties and Hybrids in Developing Countries*. Washington: USAID Bureau for Science and Technology.

World Bank (1989), *World Development Report 1989*. Washington, DC: World Bank.

World Bank (1990), *World Development Report 1990*. Washington, DC: World Bank.

World Bank (1992), World Development Report 1991. Washington, DC: World Bank.

Yaron, J. (1991), *Successful Rural Finance Institutions*. Unpublished reports, 2 Volumes. Washington DC: Agricultural Policies Division.

UNICEF INTERNATIONAL CHILD DEVELOPMENT CENTRE
ECONOMIC AND SOCIAL POLICY RESEARCH PROGRAMME

INNOCENTI OCCASIONAL PAPERS
ECONOMIC POLICY SERIES

The Economic Policy Series consists of thorough and self-contained analytical reports that usually serve as background documentation for the four main research projects currently being carried out within the Economic and Social Policy Research Programme of the ICDC.

The papers in the series (ISSN 1014-7837) are all available in English. Price: $8 each.

For more information or to order papers in the Economic Policy Series, write the Economic and Social Policy Research Group, UNICEF-ICDC, Piazza SS. Annunziata 12, 50122 Florence, Italy. Please accompany all orders with a nontransferable cheque made out to UNICEF.

EPS 1 *Economic Decline and Child Survival: The Plight of Latin America in the Eighties.* Teresa Albanez, Eduardo Bustelo, Giovanni Andrea Cornia and Eva Jespersen. Special Subseries: "Fiscal Policy and the Poor". (March 1989).

EPS 2 *Child Poverty and Deprivation in Industrialized Countries: Recent Trends and Policy Options.* Giovanni Andrea Cornia. Special Subseries: "Child Poverty in Industrialized Countries". (March 1990). Also available in French and Spanish.

EPS 3 *Education, Skills and Industrial Development in the Structural Transformation of Africa.* Sanjaya Lall. Special Subseries: "Structural Adjustment in Sub-Saharan Africa". (July 1990).

EPS 4 *Rural Differentiation, Poverty and Agricultural Crisis in Sub-Saharan Africa: Toward An Appropriate Policy Response.* Giovanni Andrea Cornia and Richard Strickland. Special Subseries: "Structural Adjustment in Sub-Saharan Africa". (July 1990).

EPS 5 *Increased Aid Flows and Human Resource Development in Africa.* Paul Mosley. Special Subseries: "Structural Adjustment in Sub-Saharan Africa". (August 1990).

EPS 6 *Child Poverty and Deprivation in Italy: 1950 to the Present.* Chiara Saraceno. Special Subseries: "Child Poverty in Industrialized Countries". (September 1990). Also available in Italian.

EPS 7 *Toward Structural Transformation with a Human Focus: The Economic Programmes and Policies of Zambia in the 1980s.* Venkatesh Seshamani. Special Subseries: "Structural Adjustment in Sub-Saharan Africa". (October 1990).

EPS 8 *Child Poverty and Deprivation in the UK.* Jonathan Bradshaw. Special Subseries: "Child Poverty in Industrialized Countries". (October 1990).

EPS 9 *Adjustment Policies in Tanzania, 1981-1989: The Impact on Growth, Structure and Human Welfare.* Jumanne H. Wagao. Special Subseries: "Structural Adjustment in Sub-Saharan Africa". (October 1990).

EPS 10 *The Causes and Consequences of Child Poverty in the United States.* Sheldon Danziger and Jonathan Stern. Special Subseries: "Child Poverty in Industrialized Countries". (November 1990).

INNOCENTI OCCASIONAL PAPERS
ECONOMIC POLICY SERIES
(Continued From Previous Page)

EPS 11 *The Fiscal System, Adjustment and the Poor.* Giovanni Andrea Cornia and Frances Stewart. Special Subseries: "Fiscal Policy and the Poor". (November 1990).

EPS 12 *The Health Sector and Social Policy Reform in the Philippines since 1985.* Wilfredo G. Nuqui. Special Subseries: "Fiscal Policy and the Poor". (January 1991).

EPS 13 *The Impact of Economic Crisis and Adjustment on Health Care in Mexico.* Carlos Cruz Rivero, Rafael Lozano Ascencio and Julio Querol Vinagre. Special Subseries: "Fiscal Policy and the Poor". (February 1991).

EPS 14 *Structural Adjustment, Growth and Welfare: The Case of Niger, 1982-1989.* Kiari Liman Tinguiri. Special Subseries: "Structural Adjustment in Sub-Saharan Africa". (March 1991).

EPS 15 *The Impact of Self-Imposed Adjustment: The Case of Burkina Faso, 1983-1989.* Kimseyinga Savadogo and Claude Wetta. Special Subseries: "Structural Adjustment in Sub-Saharan Africa". (April 1991).

EPS 16 *Liberalization for Development: Zimbabwe's Adjustment without the Fund.* Robert Davies, David Sanders and Timothy Shaw. Special Subseries: "Structural Adjustment in Sub-Saharan Africa". (May 1991).

EPS 17 *Fiscal Shock, Wage Compression and Structural Reform: Mexican Adjustment and Educational Policy in the 1980s.* Fernando Valerio. Special Subseries: "Fiscal Policy and the Poor". (June 1991).

EPS 18 *Patterns of Government Expenditure in Developing Countries during the 1980s: The Impact on Social Services.* Beth Ebel. Special Subseries: "Fiscal Policy and the Poor". (July 1991).

EPS 19 *Ecuador: Crisis, Adjustment and Social Policy in the 1980s.* The Ecuadorian Centre of Social Research. Special Subseries: "Fiscal Policy and the Poor". (August 1991).

EPS 20 *Government Expenditures for Children and Their Families in Advanced Industrialized Countries, 1960-85.* Sheila B. Kamerman and Alfred J. Kahn. Special Subseries: "Child Poverty in Industrialized Countries". (September 1991).

EPS 21 *Is Adjustment Conducive to Long-term Development? The Case of Africa in the 1980s.* Giovanni Andrea Cornia. Special Subseries: "Structural Adjustment in Sub-Saharan Africa". (October 1991).

EPS 22 *Children in the Welfare State: Current Problems and Prospects in Sweden.* Sven E. Olsson and Roland Spånt. Special Subseries: "Child Poverty in Industrialized Countries". (December 1991).

EPS 23 *Eradicating Child Malnutrition: Thailand's Health, Nutrition and Poverty Alleviation Policy in the 1980s.* Thienchay Kiranandana and Kraisid Tontisirin. Special Subseries: "Fiscal Policy and the Poor". (January 1992).

INNOCENTI OCCASIONAL PAPERS
ECONOMIC POLICY SERIES
(Continued From Previous Page)

EPS 24 *Child Welfare and the Socialist Experiment: Social and Economic Trends in the USSR, 1950-90.* Alexandr Riazantsev, Sándor Sipos and Oleg Labetsky. Special Subseries: "Child Poverty in Industrialized Countries". (February 1992).

EPS 25 *Improving Nutrition in Tanzania in the 1980s: The Iringa Experience.* Olivia Yambi and Raphael Mlolwa. Special Subseries: "Fiscal Policy and the Poor". (March 1992).

EPS 26 *Growth, Income Distribution and Household Welfare in the Industrialized Countries since the First Oil Shock.* Andrea Boltho. Special Subseries: "Child Poverty in Industrialized Countries". (April 1992).

EPS 27 *Trends in the Structure and Stability of the Family from 1950 to the Present: The Impact on Child Welfare.* Chiara Saraceno. Special Subseries: "Child Poverty in Industrialized Countries". (May 1992).

EPS 28 *Child Poverty and Deprivation in Portugal: A National Case Study.* Manuela Silva. Special Subseries: "Child Poverty in Industrialized Countries". (June 1992).

EPS 29 *Poverty Measurement in Central and Eastern Europe before the Transition to the Market Economy.* Sándor Sipos. Special Subseries: "Child Poverty in Industrialized Countries". (July 1992).

EPS 30 *The Economics of Disarmament: Prospects, Problems and Policies for the Disarmament Dividend.* Saadet Deger. Special Subseries: "Fiscal Policy and the Poor". (August 1992).

EPS 31 *External Debt, Fiscal Drainage and Child Welfare: Trends and Policy Proposals.* Stephany Griffith-Jones. Special Subseries: "Fiscal Policy and the Poor". (September 1992).

EPS 32 *Social Policy and Child Poverty: Hungary since 1945.* Júlia Szalai. Special Subseries: "Child Poverty in Industrialized Countries". (October 1992).

EPS 33 *The Distributive Impact of Fiscal and Labour Market Policies: Chile's 1990-1 Reforms.* Mariana Schkolnik. Special Subseries: "Fiscal Policy and the Poor". (November 1992).

EPS 34 *Changes in Health Care Financing and Health Status: The Case of China in the 1980s.* Yu Dezhi. Special Subseries: "Fiscal Policy and the Poor". (December 1992).

EPS 35 *Decentralization and Community Participation for Improving Access to Basic Services: An Empirical Approach.* Housainou Taal. Special Subseries: "Fiscal Policy and the Poor". (January 1993).

EPS 36 *Two Errors of Targeting.* Giovanni Andrea Cornia and Frances Stewart. Special Subseries: "Fiscal Policy and the Poor". (March 1993).

EPS 37 *Education and the Market: Which Parts of the Neo Liberal Solution are Correct?* Christopher Colclough. Special Subseries: "Fiscal Policy and the Poor". (July 1993).

EPS 38 *Policy and Capital Market Constraints to the African Green Revolution: A Study of Maize and Sorghum Yields in Kenya, Malawi and Zimbabwe, 1960-91.* Special Subseries: "Structural Adjustment in Sub-Saharan Africa". (December 1993).

⊙ stampa centrooffset, siena

International Child Development Centre
Piazza S.S. Annunziata, 12
50122 Florence, Italy
Tel. 3955-234-5258 - Fax 3955-244817
Telex 572297 UNICEF I