KENYA AGRICULTURAL MARKETING AND POLICY ANALYSIS PROJECT

TEGEMEO INSTITUTE OF AGRICULTURAL POLICY AND DEVELOPMENT/ EGERTON UNIVERSITY

KENYA AGRICULTURAL RESEARCH INSTITUTE

MICHIGAN STATE UNIVERSITY

MAIZE PRODUCTIVITY AND IMPACT OF MARKET LIBERALIZATION IN KENYA

by

Daniel D. Karanja, Thomas S. Jayne, and Paul Strasberg

Support for this study was provided under the Kenya Agricultural Marketing and Policy Analysis Project (KAMPAP), supported by the United States Agency for International Development/Kenya.

Karanja is a Ph.D. student at Michigan State University and also an environment and resource economist with the Kenya Agricultural Research Institute (KARI); Jayne is a visiting associate professor at MSU; and Strasberg is a research scholar at the Land Tenure Center, University of Wisconsin.

1. INTRODUCTION

Most countries in Africa are facing an imminent food crisis. Whereas at independence most of these economies were self-sufficient in food production, the combination of recurrent oil crises of the 1970s, increasingly adverse weather, poor macroeconomic and sectoral performance in the 1980s and 1990s, and declining public investment in infrastructure undermined the capacity of these economies to supply sufficient food from domestic sources. Further, rapid population growth and a persistent decline in the natural resource base resulted in a decline in per capita food production and unmet food demand. The ultimate effect of these is reflected in a growing reliance on food imports and food aid, increased poverty and civil strife. Increasing food productivity is, thus, vital for enhancing future food security, peace and health. With an expected doubling of Africa's current population to about 1.3 billion by 2020, addressing the continent's food crisis will require great wisdom and vision. However, since most African households are engaged in agriculture, the alleviation of poverty, hunger and malnutrition will be expedited through improved agricultural productivity caused by greater investment in economic growth that provides demand for rural nonfarm products and greater technical change (Byerlee and Eicher 1997).

Kenya is no exception in many regards. It has a predominant agrarian economy. The major staple crop, maize, is grown in almost all agro-ecological zones in two out of every three farms. In the past two decades, the country has shifted from being a net food exporter to a persistent net importer due to policy and demographic factors mentioned above. Domestic maize demand outstrips domestic production in six out of ten years, leading to increasing reliance on imports to bridge the gap. This is in spite of a tremendous maize production potential exhibited between 1964-75, fueled by the introduction of maize hybrids and related technologies, often dubbed "Kenya's Green Revolution" (Karanja 1996). Figure 1 shows trends in maize area, yield and production from 1963-1997.

That Kenya must increase its farm productivity and income is no longer debatable but is a great necessity. Over 85% of the population derive its livelihood from agriculture, most of whom engage in maize production. With maize occupying such a central position in Kenyans' diets and farm production activities, it is imperative that ways and means of improving maize productivity be sought. Evidence from recent years indicates that average maize yields and area have stagnated at below 2 tons per hectare and about 1.5 million hectares, respectively (Figure 1). Given the limited arable land area and low irrigation development capacity, there is no doubt that Kenya will have to rely relatively more on yield improvement than area expansion for future increases in maize production.

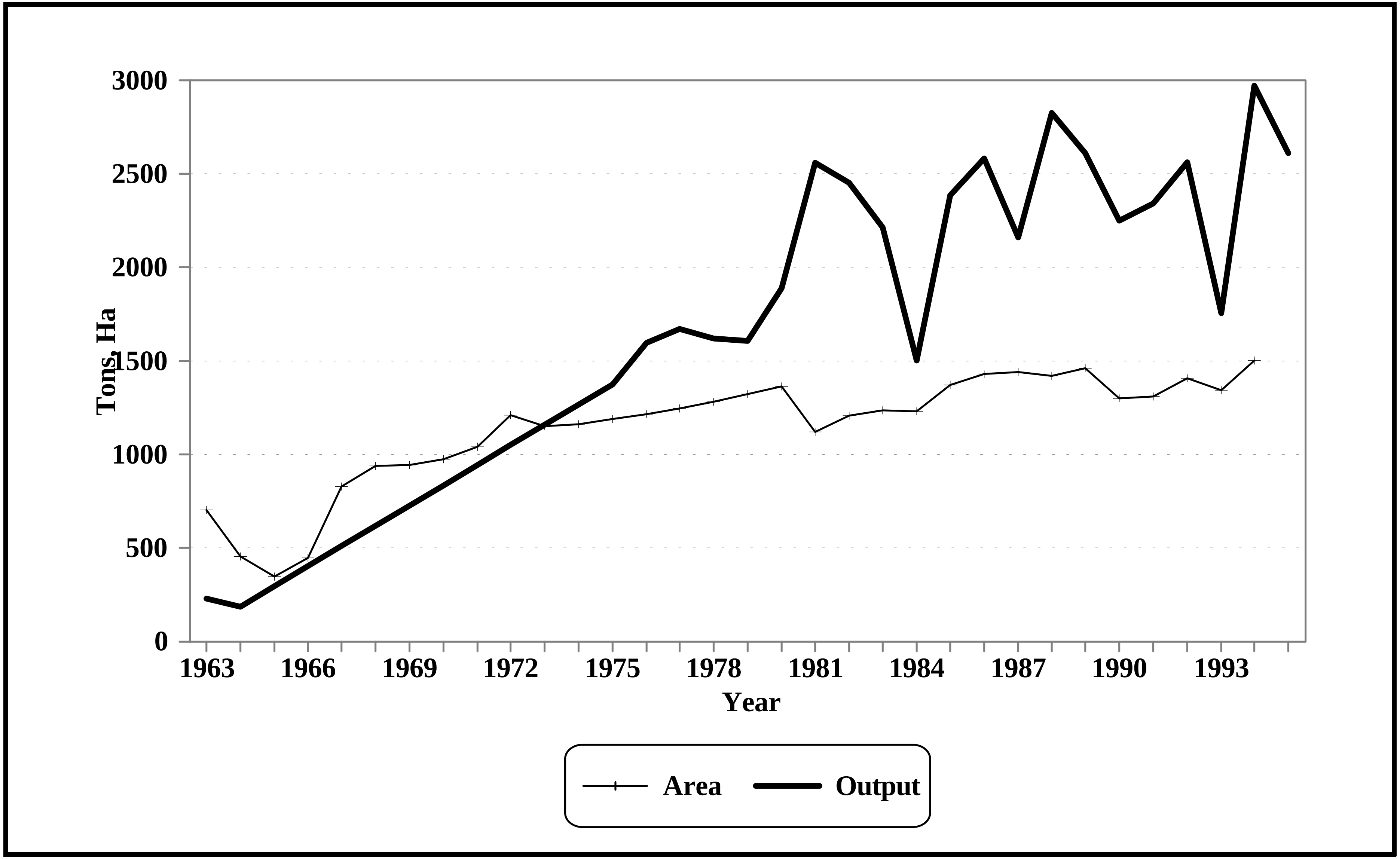


Figure 1. Maize Area and Output in Kenya, 1963-94

The Kenya Agricultural Research Institute has an uphill task of generating and adapting better maize technologies to local conditions, more so the latter than the former, on low and dwindling research funding. Meanwhile, the extension program of the Ministry of Agriculture should seek a more cost-effective means of using its extensive network of extension agents to supply farmers with basic and sound agricultural advice. Moreover, past success in maize production was achieved by exploiting the tremendous synergy between the technology development, dissemination and seed multiplication and distribution programs (Karanja 1996). Lack of adequate funding, poor research-extension-farmer linkage, low private investments in maize research and development, and high human capital turn-over are problems that must receive adequate attention and resolve if a new way forward is to be charted. Needless to say, the government must continue providing an enabling environment through clear policy goals and commensurate investments in infrastructure, education and information technology which are public good assets that have in the past proven to be important pre-requisites for agricultural and economic productivity growth.

Although numerous studies in the recent past have explored and discussed ways and means of increasing maize productivity in Kenya, this study takes the issue further and explores the impact of recent market reform policies, specifically maize market liberalization, on maize productivity. The latter is critical considering the level of expectations that greeted the reform process back in the early 1990s. Removal of input and grain price controls was meant to reduce the government's budgetary burden, mainly through diminished activities of the National Cereals and Produce Board, and encourage private sector participation in maize trade. This was considered useful in two ways (1) to reduce transaction costs of marketing and distributing maize, thereby improving trade incentives for both traders and farmers; and (2) to improve access to food by low-income urban consumers and net buyers in maize-deficit regions. The impacts of market liberalization have ranged from greater private sector participation in maize trading to perceived reduction in farm gate maize prices. However, these impacts are hard to discern for three reasons. First, they are difficult to isolate from other macro-economic policy and weather-induced effects. Two, the reform process has neither been smooth nor complete. Instead, it has been subjected to frequent reversals and holding patterns. Only recently have decisive reform measures been taken. Finally, weak and partial data has reduced the capacity to investigate the impact of reforms on productivity. This paper explores the determinants of, and investigate the impact of market reforms on, maize productivity.

The paper is organized as follows: the following section discusses methodology, data, and the models used in this study. Section 3 discusses the regression results of determinants of maize hybrid and fertilizer adoption, and productivity. Section 4 estimates the impact of market liberalization on maize productivity and Section 5 presents conclusions and implications.

2. Methodology, Data Setting and Model Specification

2.1. Methodology

Past empirical studies used different methodology ranging from linear to log-linear and non-linear regression models to estimate the determinants of adoption and productivity of agricultural technologies. Adoption was mainly expressed in terms of the percentage of the area cultivated by farm households with the new technology over total cultivated area. Non-adopters were often excluded from the sample, thus resulting in a sample selection bias and consequent biases in the estimated coefficients (Heckman 1979; Feder and Umali 1993). Inclusion of non-adopters also yielded biased and inconsistent estimates since clustering of observations, in this example the prevalence of zero-values of the dependent variable, violated the ordinary least square (OLS) assumptions of a continuous variable. Estimation of OLS with a dichotomous variable was also inappropriate because the error structure was generally heteroscedastic and the resulting parameters inefficient. For dichotomous adoption decisions, logit and probit models have been used. The adoption variable is expressed in binary form (1 if the farmer adopts and 0 if he or she does not). If the error term are assumed to follow a normal distribution, the result is the probit model; if it is assumed to follow a logistic cumulative distribution, the result is a logit model (Maddala 1983). Empirical examples using these models include Jamison and Lau (1982), Rahm and Huffman (1984), Duraisamy (1989) and Strauss et al. (1991), among many others. Farmers are essentially hypothesized as making their technology investment decisions to maximize expected net returns given their production constraints. In this study, they are modelled as following a sequential adoption process: first choosing from two basic types of maize varieties, grouped into hybrids and non-hybrids, and then independently deciding on whether or not to use fertilizer, subject to household resources and locational constraints.[1]

2.2. Data and Setting

The study used data from a survey of 1,540 rural households carried out in 1997 in Kenya using a population-proportion sampling procedure under the Kenya Agricultural Marketing and Policy Analysis Project, a collaborative project of the Tegemeo Institute of Egerton University, the Kenya Agricultural Research Institute and Michigan State University. For the purpose of this study, the total sample was grouped into eight agro-regional zones: Coastal Lowlands (80), Eastern Lowlands (166), Western Lowlands (188), Western Transitional (172), Western Highlands (156), Central Highlands (327) and High Potential Zone (386), drawn from 21 districts.[2] Three districts, namely Garissa, Turkana and Narok, were excluded from this analysis because of representation and data problem. The study uses data of all farmers with farm sizes of less than 50 acres, making it a primarily smallholder farm analysis.

[1]Maize variety and fertilizer choice decisions are assumed to be the major production technology decision facing the farmer.

[2]Unlike the other reports produced using this household data set, Laikipia district was classified under the Central Highlands zone because it fitted this category for maize production.

This focus is maintained because smallholder farmers account for the largest proportion of maize production in Kenya, and because input use decisions may differ for large-scale farmers. Further, quarterly maize price data, used to simulate the impact of maize market liberalization on productivity, was compiled from monthly data collected by the Ministry of Agriculture's Market Information System Bureau.

Table 1. Maize Productivity and Adoption of Hybrids and Fertilizer by Agro-Regional Zones

Agro-Regional Zone	Sampled Districts[2]	Mean Value of Production (Kshs/acre)	% Farmers Using Hybrids	% Farmers Using Fertilizer
Coastal Lowlands	Kilifi	4535	36	36
	Kwale	10688	31	6
	Taita Taveta	4203	56	18
Average		**5735**	**38**	**28**
Eastern Lowlands	Kitui	1398	10	5
	Mwingi	3099	3	51
	Machakos	2817	5	9
	Makueni	8540	53	39
Average		**5506**	**28**	**33**
Western Lowlands	Kisumu	6443	27	3
	Siaya	5356	10	4
Average		**5996**	**20**	**3**
Western Transitional	Bungoma (1)	8789	100	74
	Kakamega(1)	6290	61	49
Average		**7015**	**72**	**44**
Western Highlands	Kisii	8356	86	65
	Vihiga	7900	52	65
Average		**8173**	**72**	**65**
Central Highlands	Muranga	10780	86	93
	Nyeri	10392	85	71
	Meru	15226	100	88
	Laikipia	3808	84	35
Average		**10946**	**89**	**74**
High-Potential	Trans-Nzoia	15611	89	72
	Uasin Gishu	14465	97	84
	Bomet	11581	100	81
	Nakuru	13356	97	74
	Bungoma(2)	11496	84	84
	Kakamega(2)	12784	93	96
Average		**13576**	**94**	**80**
Total		**9503**	**68**	**56**

[1] Bungoma(1) comprises of Kanduyi Division; Kakamega(1): Kabras and Mumias divisions; Bungoma(2): Kimilili and Tongaren divisions; and Kakamega(2) Lugari Division.

Table 1 shows the value of maize productivity, in Kenyan shillings per acre (Kshs/Acre) and the percentage adoption of hybrids and fertilizer by agro-regional zone.[3] Maize productivity is highest, as expected, in the High-Potential Zone followed by the Central Highland Zone. Eastern Lowland and Coastal Lowland zones registered the lowest level of productivity. When considered by districts, Trans-Nzoia, Meru and Nakuru posted the highest values of productivity in that order, while Kitui, Machakos and Mwingi had the lowest. The difference between the levels of productivity is attributed to a difference in the choice of maize technology and related yield differential, the agro-regional production potential. Generally, farmers in the highlands tend to do better due to better soils, rainfall, investments in improved maize technologies and the possibility of higher valued complementary crops compared to those in the lowlands.

Table 2. Variation of Maize Productivity by Agro-Regional Zone

Agro-Regional Zone	Productivity Quartiles (Kshs/Acre)				Mean Productivity (Kshs/Acre)
	25%	50%	75%	95%	
Coastal Lowlands	1680.27	3094.22	6073.15	22508.82	5735
Eastern Lowlands	1215.55	2264.94	4824.83	15341.67	5505
Western Lowlands	2101.64	3779.16	7020.14	13756.77	5996
Western Transitional	3628.12	5784.38	9330.15	18516.61	7015
Western Highlands	4127.46	6079.26	10350.75	23424.98	8173
Central Highlands	4284.8	8101.61	13476.96	31369.5	10946
High-Potential	7963.25	12318.68	16881.74	26533.88	13576

This difference is also exhibited within the zones (Table 2). For instance, after ranking all the households by level of productivity, the level in the Coastal Lowland increases from about 1700 Ksh/acre for the bottom quartile of the households to about 22500 Ksh/acre for the top quartile. In the Eastern Lowlands, the range is from 1200 to 15300 Ksh/acre, in the Central Highlands it is 4300 to 31400 Ksh/acre, and in the High-Potential Zone, the range is from about 8000 to 26500 Ksh/acre, respectively. These values reveal considerable intra-zonal

[3]Value of maize productivity is measured as the value in Kenya Shillings per acre of maize crop-system, which includes intercrop(s).

variation. Notably, this variation is greater than the mean inter-zonal variation, spelling a great opportunity for productivity growth if the level of productivity for the lower half of the farmers within each of the zones can be bolstered to reach the mean level of productivity.

Figure 2 contrasts productivity among hybrid and non-hybrid producers by fertilizer use level and grouped agro-regional zones, that is, in low, transitional and high potential zones. The level of productivity is consistently higher for hybrids than non-hybrids in all agro-regional zones and fertilizer levels. For almost all regions, productivity increases as fertilizer use increases. Similarly, productivity is higher in the highlands compared to the lowlands, irrespective of the variety. Moreover, holding region constant, productivity levels are higher for farmers using hybrid seeds as opposed to non-hybrids. Even without fertilizer, hybrids are more productive than non-hybrids. This has a great implication for varietal targeting since the general tendency is for farmers to grow non-hybrids when they lack access to fertilizer. It also indicates that if current hybrids can be adapted to the relatively low moisture stress of the lowlands, then farmers can realize even higher levels of productivity.

2.3. Model Specification: Determinants of Productivity

Several models were estimated in this study. A probit model was used to estimate the determinants of hybrid varietal adoption, a tobit model used to explore the determinants of fertilizer use and a two-stage least square model with instrument variables to assess factors influencing productivity. Conventional wisdom has it that constraints to rapid adoption of agricultural technologies include lack of credit, limited access to extension, smaller farm size, inappropriate land tenure system, insufficient human labor and capital, absence of mechanized options to ease labor constraints, lack of access and untimely supply of farm inputs and inappropriate transport and marketing facilities (Feder and Umali 1993).

Several studies have found that credit, either in the form of accumulated savings or access to capital markets, is needed to overcome fixed investment costs associated with adoption of new technologies. Thereby, differences in access to capital is found to create a differential rate of adoption. This is even more explicit in cases of “lumpy” technologies, such as a tractor, which often require a large initial capital outlay (Lowdermilk 1972; Lipton 1976). Credit access has been found to be a major bottleneck to maize producers in Kenya, especially smallholder farmers (Karanja 1990).

Several studies have reported that technology adoption is related to farm size. For instance, some studies indicate that large farmers demonstrate a higher adoption rate for hybrids (Barker and Herdt 1978) while others contend that smaller farmers have higher intensity of adoption than large farmers (Schluter 1971; Sharma 1973). The latter is found to be the case where the technology has low fixed investment costs. In some cases, it has also been found that smallholders initially lag behind large farmers in adopting the technologies but eventually catch up (Ruttan 1977). Hybrid maize adoption in Kenya is a good example of such a case (Hassan and Karanja 1997). Other studies have found a negative relationship between intensity of use of modern inputs and farm size. Such findings may be tied to possibly greater risk aversion by small farmers, risk effects of inputs and the relationship between credit and farm size.

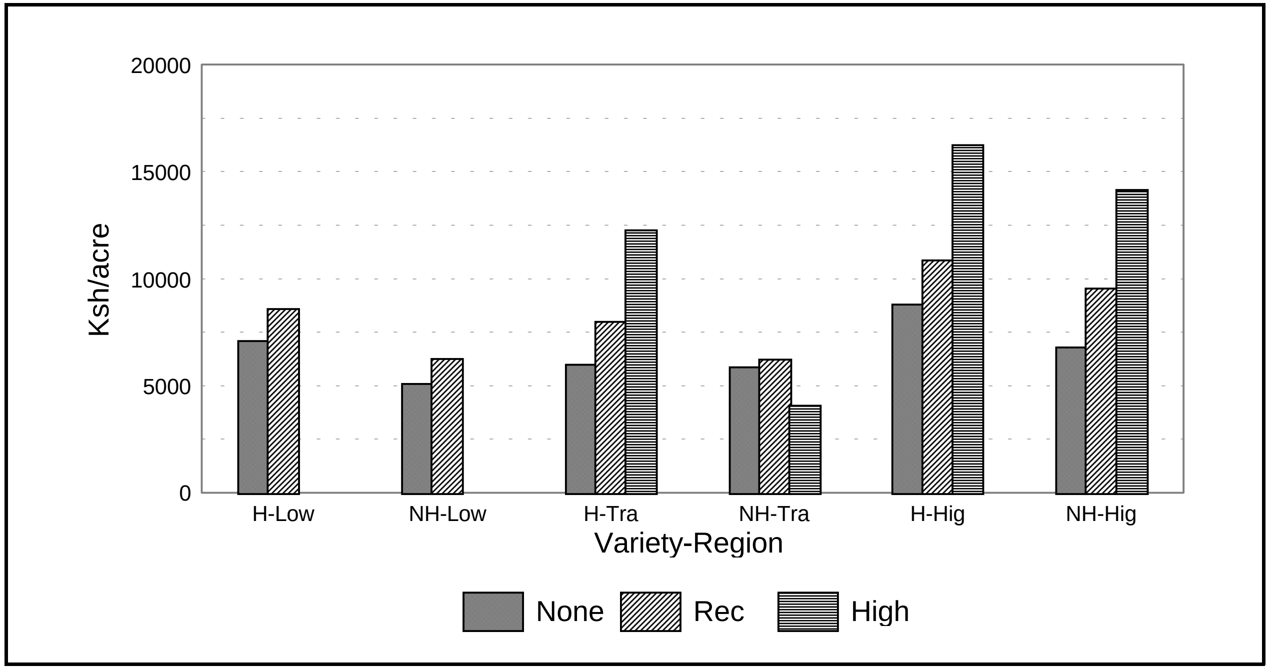


Figure 2. Maize Productivity by Variety, Region and Fertilizer Level

Key: H=Hybrid; NH=Non-Hybrid; Low=Lowland zone Tra=Transitional zone; Hig=Highland zone; None= 0 Kg/acre, Rec=0-32 Kg/acre and High=32-216 Kg/acre of Fertilizer Nutrient

Beyond the profit motive, farmers may be interested in replacing heavy demand on human labor, especially where reliance on family labor is greater and most members are engaged in off-farm employment or schooling. In such cases, choices of labor and levels of mechanization options become important considerations when it comes to adopting new technologies. Some technologies are labor saving while others are not. Hybrids often require more labor input to achieve significant yield improvements over traditional varieties, so that labor shortages may prevent adoption. Moreover, new technologies may increase seasonal labor demands so that adoption is less attractive to households with limited family labor or low access to hired labor. Often, a switch to ox or tractor power, aimed at alleviating labor bottlenecks, provide for timely farming operations and allow increased production. Hicks and Johnson (1974) found that higher rural labor supply fueled adoption of labor intensive rice varieties in Taiwan.

But investments in fixed inputs such as farm machinery have sometimes been affected by the type of land tenure arrangement, so that the relationship with technology adoption becomes unclear. Parthasarathy and Prasad (1978) found that tenants had a lower tendency to adopt hybrid seeds than land owners. Schutjer and Van der Veen (1977) suggested that the relationship between land tenure and adoption could be related to the implied relationship between tenure and credit access, input and product markets, and access to technical information, which are often not accounted for in such studies.

Other important constraints to adoption of technologies are access to extension information, education, availability of complementary inputs and lack of transport and marketing infrastructure. Farmers with access to extension services, better education and access to markets are more likely to adopt new technologies than those who do not. Formal schooling has been found to influence farmer’s allocative efficiency and managerial capacity. Evenson (1981) suggested that farmers with better education were likely to be earlier adopters and apply modern inputs more efficiently. Gerhart (1975) and Rosenzweig (1978) found that the likelihood of adoption of hybrid seed was positively related to education. Jamison and Lau (1982) found that education, age and extension had positive effect on the likelihood of adoption.

This study hypothesizes that farm size, access to extension, markets and roads, education level of household members, gender, family labor and labor-age categories, maize price and agro-regional potential will influence the likelihood of adoption of hybrid maize, and the adoption and intensity of fertilizer use. A probit model is used to capture determinants of the farmers' varietal choice.[4] A tobit models the fertilizer determinants since, unlike for seed, the level of use is also important and because of the prevalence of zero-value observations. The models are as follows:

Probit Equation:

HYBRID = *f(ASSET, ROAD, ACREOWN, EDU2, EDU3, EXT1, EXT2, HHMEMBER, AM, AMPRES, PCT616, PCT40P, PCT1739, PMAIZE, NZ1, NZ2, NZ3, NZ5, NZ6, NZ8)*

and the

---

[4] An alternative specification of the quantity of hybrid seed used per acre was possible, but this variable was clearly not normally distributed, having a high number of zero values and with the non-zero values clustering around several peaks of close proximity.

Tobit Equation:

FERT = *g(ASSET, FERTKM, PDAP, HYBRID, NZ1HYB, NZ2HYB, NZ3HYB, NZ5HYB,*

NZ6HYB, NZ8HYB, ACREOWN, EDU2, EDU3, EXT1, EXT2, HHMEMBER, AM, AMPRES, PCT616, PCT40P, PCT1739, PMAIZE, NZ1PMZ, NZ2PMZ, NZ3PMZ, NZ5PMZ, NZ6PMZ, NZ8PMZ, NZ1, NZ2, NZ3, NZ5, NZ6, NZ8, NZ1PDAP,NZ2PDAP NZ3PDAP NZ5PDAP NZ6PDAP NZ8PDAP)

Further, a two-stage least square maize productivity model is estimated as follows:

VALUE = *h(FERT, HYBRID ASSET, ROAD, ACREOWN, EDU2, EDU3, EXT1, EXT2, HHMEMBER, AM, AMPRES, PCT616, PCT40P, PCT1739, NZ1, NZ2, NZ3, NZ5, NZ6, NZ8)*

To deal with the potential endogeneity problem of *FERT* and *HYBRID*, these variables were instrumented using the *FERTKM* and *PDAP*, and *HYBRID95* Variable definition and measurement units are listed in Table 3. *HYBRID* is a dichotomous variable identifying farmers using hybrid maize. *HYBRID95* represent farmers who used hybrid maize the previous year (1995). *ASSET* is the total value agricultural equipment and livestock owned by the farm household. Household with greater asset value are more likely to adopt hybrids, use fertilizer and achieve higher productivity. *ROAD* is a measure, in kilometers, of proximity to a motorable road and is used as proxy to access to the seed, fertilizer and grain markets. Distance to the market has been found to be a key issue in productivity analysis although, in Kenya, the quality of roads is also becoming an important issue in this debate. Access to market and related transportation costs were found to affect crop choice decisions in Siaya District, Kenya (Omamo 1998).

ACREOWN is the total land area, in acres, owned by the household. Hybrid seed and fertilizer adoption are expected to exhibit scale economies with larger farmers being earlier and higher adopters. However, this seems to hold in the case of lumpy technologies since they tend to have better access to credit. *EDU2* and *EDU3* represent the highest level of education attained, with the former representing secondary school level and the latter post-secondary education. This is a measure of household human capital. The greater this is, compared to no-education or primary-level education, the more likely is the household to adopt hybrids and fertilizer due to better access of information and the ability to use the new technologies. *EXT1* and *EXT2* measure the number of years, 1-2 and 3-5 years respectively, since the household had contact from extension agents. Household with more access to extension are hypothesized to be more likely to adopt new technologies.

Table 3. Regression Variable Description and Measurement Units

Variable	Description	Units
FERT	Level of fertilizer nutrients	kg/acre
FERTKM	Distance to nearest fertilizer trader	km
ROAD	Distance to nearest motorable road	km

Variable	Description	Units
PDAP	Price of DAP fertilizer	Ksh/ton
HYBRID	Whether farmer uses hybrid or not	1/0 (1=hybrid, 0=else)
ASSET	Value of livestock assets	Ksh
ACREOWN	Total farm area owned	Acres
EDU2	# family members with primary education	#
EDU3	# family members with college degree	#
EXT1	received extension contact last 1-2 years	1/0 (1=received, 0=else)
EXT2	received extension contact last 3-5 years	1/0 (1=received, 0=else)
HHMEMBER	Total # of family members	#
ABSTM	Household without male at all	1/0 (1=without male, 0=else)
AMPRES	Household with absent male	1/0 (1=absent male, 0=else)
PCT616	Proportion of household between 6-16 yrs	%
PCT40p	Proportion of household between 17-36 yrs	%
PCT1739	Proportion of household over 40 yrs old	%
PMAIZE	District-average maize price	Ksh/Kg
NZ1	Coastal lowland	1/0 (1=coastal lowland)
NZ2	Eastern lowland	1/0 (1=eastern lowland)
NZ3	Western lowland	1/0 (1=western lowland)
NZ5	High potential zone	1/0 (1=high potential)
NZ6	Western highland	1/0 (1=western highland)
NZ8	Central highland	1/0 (1=central highland)

HHMEMBER refers to the total family size. This is used as a proxy to the amount of family labor available to the household and is expected to positively influence productivity in regions dominated by manual tillage systems and negative in regions in which tillage and/or weeding operations are highly mechanized. *AM* and *AMPRES* represent households in which the male is resident on-farm and where the male exists but not necessarily resident on-farm, respectively. This differentiation was been inspired by increasing interest in gender effects on agricultural productivity. *PCT616, PCT40P* and *PCT1739* are labor-age categories and represent the proportion of household members that are within the 6-16 years age category, over-40 years age category and between 17-39 years age category, respectively. *PMAIZE* is the district-average maize grain price. The higher the price, the greater the inducement to adopt new technologies and improve productivity. *NZ1, NZ2, NZ3, NZ5, NZ6, NZ8* are dummy variables for Coastal Lowland, Eastern Lowland, Western Lowland, High Potential, Western Highland and Central Highland agro-regional zones, respectively.

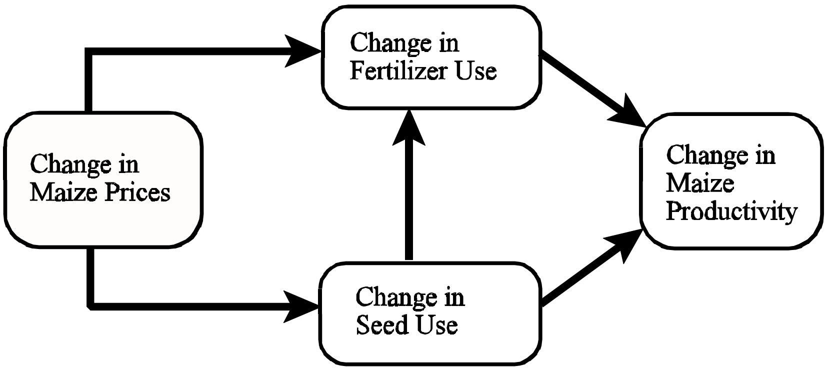
FERT is the level of fertilizer nutrient used on maize per acre, *FERTKM* the distance to fertilizer market and *PDAP* the price of Di-Ammonium Phosphate fertilizer, the most commonly used maize fertilizer. *FERT* is expected to be inversely related to *FERTKM* and *PDAP*. *NZiHYB, NZiPMZ* and *NziPDAP*, where *i=1...8* as per the zones, are interaction terms between the agro-regional zones and *HYBRID, PMAIZE* and *PDAP*, respectively. These account for hypothesized variation across zones in the effect of hybrid usage, the price of maize and the price of fertilizer. Finally, *VALUE* is a measure of land productivity, as the total value of maize production, including intercrops where applicable, in Ksh/Acre.

2.4. Model Specification: Impact of Market Reforms

In estimating the impact of market liberalization on maize productivity, Figure 3 outlines several important hypothesized pathways by which the reform process may affect productivity. First, changes in maize price levels due to reform may affect incentives to use purchased inputs such as fertilizer and hybrid seed, thereby affecting maize productivity. The relationship between maize price and input use has been explored in Kenya by Muturi (1989), Mose (1997), Ongaro (1988) and Mwangi (1978). Second, input use and maize productivity may be affected by changes in the variability of maize output prices. The empirical record indicates that output price variability generally has a negative, but not always large or significant effect on input use and production. Third, institutional changes in the way the maize sector is organized may also affect input use and productivity in a variety of ways not directly measured by changes in price. These non-price factors are increasingly being recognized as critical determinants of the way the food system operates. Unfortunately, this is an area where currently the analytical framework and associated data are relatively weak. While acknowledging the importance of these various pathways affecting input use and productivity, the analysis in this study is confined to the first pathway, that is, the impact of price changes due to maize market liberalization on maize productivity.

This study examines the direction of maize prices in selected markets, and estimates the effect of market liberalization on price levels after controlling for other exogenous factors. Then, using parameter estimates from the econometric models estimated elsewhere in this section,

Figure 3. Hypothesized Pathways by Which Maize Prices May Affect Maize Productivity



the impact of the change in maize price levels on the use of hybrid seed and fertilizer, were simulated and traced through the effects on maize productivity.

Three periods were distinguished. First, the control period, which starts first quarter of 1985 (the starting point of the data used) until when the cereal sector reform programme was initiated in 1989. Second, the initial reform period, termed Phase 1 Reform period between the first quarter of 1989 to the fourth quarter of 1993, which was characterized by only partial lifting of the inter-district controls on private maize trade, the continued dominance of the NCPB in maize purchase and sales, and the continuation of controls on producer and consumer maize prices through the formal sector marketing channel. The Phase 2 Reform period, the first quarter 1994 to the third quarter 1998, was characterized by complete decontrol of domestic maize movement and maize meal prices, and an almost negligible role of the NCPB in maize purchases.

Before proceeding to the impact model, unit root tests, both Philips-Peron (PP) and augmented Dickey Fuller (ADF) tests, were performed on all market price series to guide model specification. The PP test rejected the assumption of non-stationarity in the data for 7 of the 8 selected markets, while the ADF rejected non-stationarity in 6 of 8 of them. Based on these results in support of stationarity, the models to examine the effects of market reform on maize prices were estimated in levels and specified as follows for each market:

(1) $$P_{it} = \alpha_i + \Sigma\ \beta_{ni}\ Q_{nt} + \ \gamma_i RAINma3_{it-2} + \ \delta_{i1} DLIB1_t + \ \delta_{i2} DLIB2_t + \ \Sigma\rho_{ij} P_{it-j} + \varepsilon_{it}$$

where P_{it} are real wholesale prices for maize in i = 1....8 markets; Q_n are quarterly seasonal dummy variables; and $RAINma3_{t-2}$ is the 3-quarter centered moving average of rainfall, lagged two quarters, at the nearest meteorological station for which data was available. *DLIB1* and

DLIB2 are categorical variables measuring the effects of market reform. *DLIB1* takes on a value of 1 during the Phase 1 reform period and zero otherwise. *DLIB2* takes on a value of 1 during the Phase 2 reform period and zero otherwise. P_{it-j} is lagged dependent variable for $j = 1..m$ quarterly lags. Criterion for lag length for the dependent variables is the minimum number of lags required to purge the error term of autocorrelation, using Ljung-Box Q test in OLS. Using the appropriate lag lengths based on these initial OLS specification tests, the model was estimated simultaneously for each market using Seemingly Unrelated Regression (SUR). The rationale for using such a maximum likelihood estimator was that market price residuals are unlikely to be independent across markets, so that the use of SUR increase estimation efficiency by exploiting information in the cross-equation error covariance matrix.

The main coefficients of interest in the models were the δ_1 and δ_2, which measure the effects of the partial (Phase 1) and more comprehensive (Phase 2) market reforms on maize price levels after controlling for other factors such as seasonality and rainfall. These coefficients were then used to simulate the effect of changes in maize price due to market reform on the use of inputs in maize production and the associated changes in maize productivity.

More specifically, the three pathways in which the change in maize prices may affect productivity levels, as outlined in Figure 3, are:

a. Effect of change in maize price on fertilizer use, and subsequent effect on productivity. This is derived as:

$$dQ = [\ \partial Q/\partial Fert * \partial Fert/\partial Pmz\ ] * dPmz$$

where dQ is the change in productivity of the household's plots with maize; $\partial Q/\partial Fert$ is the coefficient on fertilizer use from the productivity model , and $\partial Fert/\partial Pmz$ is the coefficient on maize price in the Tobit model, adjusted by the percentage of households in each zone that used fertilizer.

b. Effect of change in maize price on hybrid seed use and subsequent effect on productivity. This is derived as:

$$dQ = [\ \partial Q/\partial HYB * \partial HYB/\partial Pmz\ ] * dPmz$$

where dQ is defined as above, $\partial Q/\partial HYB$ is the coefficient on hybrid seed use from the productivity model; $\partial HYB/\partial Pmz$ is the coefficient from the Probit model, adjusted by the percentage of households using hybrids in each zone; and $\partial Fert/\partial Pmz$ is defined as above.

c. Effect of change in maize price on hybrid seed use, which further affects fertilizer use and hence productivity.

$$dQ = [\ \partial Q/\partial Fert * \partial Fert/\partial HYB * \partial HYB/\partial Pmz\ ] * dPmz$$

The results of these computations are discussed in Section 4.

3. FACTORS INFLUENCING INPUT USE AND MAIZE PRODUCTIVITY: MAIN RESULTS

3.1. Determinants of Hybrid Maize Adoption

Table 4 depicts results of the probit regression for hybrid maize adoption. The results indicate that farmers with more assets are more likely to adopt hybrid maize. For small farmers, certain farm stocks, such as small livestocks, are readily converted to cash to meet immediate cashflow needs such as purchase of seed. For others, certain farm equipment can be used as collateral to obtain credit to purchase farm inputs. In both cases, because of the extent and nature of asset holdings, farmers with more assets get better access to hybrids. Farmers with a higher level of education, especially at post-secondary level, and received extension contact in the past 3-5 years, have a higher probability of adopting hybrids. However, those living further from a motorable road are less likely to adopt the hybrids.

The price of maize positively influences the decision to adopt hybrids. There is no scale effect on hybrid adoption. This may reflect the effect of the great coverage of seed stockists in smallholder regions and the decision to package seed in small amounts, both of which have been found to significantly contribute towards hybrid adoption by smallholder farmers (Karanja 1996). The agro-regional zone variables showed significant variations across zones in hybrid adoption. The zonal variables mostly capture climatic and soil variations that often tend to be significant criteria for varietal selection. Considering that hybrids are targeted for the highlands, it is not surprising that farmers in the high potential regions had a higher likelihood of adopting hybrids. The coefficients on Coastal, Eastern and Western lowland zone variables showed expected negative likelihood for hybrid adoption compared to the more modest Western Transitional zone, the left-out zone. Size of family, its age-composition and gender had no significant effect on the probability of hybrid adoption.

3.2. Determinants of Fertilizer Use

The results of the tobit model used to assess the determinants of fertilizer adoption and use are reported in Table 5. The results indicate that the fertilizer adoption and intensity of use is adversely affected by distance to fertilizer market and its price. Farmers closer to market tend to use more fertilizer. Farmers using hybrid seed use more fertilizer with this effect varying with agro-regional zone. This points to the expected complementarity between fertilizer and hybrid seed use. There is no scale effect on the use of fertilizer, a result similar to the case of hybrid seed adoption. Education, at post-secondary level, price of maize and extension positively influence use of fertilizer. Farmers with higher education tend to adopt and use more fertilizer. This could be because they are able to use recommendations better or have a better ability to evaluate the difference fertilizer makes to productivity. The magnitude of the relationship between the price of maize and fertilizer use varies with agro-regional zones. The effect of the price of fertilizer on fertilizer use was also found to vary by agro-ecological zone. Value of assets, gender, size of family, and age-composition of the family had no significant impact on fertilizer use.

Table 4. Probit Results for Hybrid Adoption

Probit Estimates | Number of obs = 1434
chi2 (20) = 639.88
Prob > chi2 = 0.0000
Log Likelihood = -576.04026 | Pseudo R2 = 0.3571

hybrid	dF/dx	Std. Err.	z	P>|z|	x-bar	[95% C.I.	]
asset	7.41e-07	2.59e-07	2.78	0.005	65678.4	2.3e-07	1.2e-06
road	-.0509712	.0149574	-3.41	0.001	1.14175	-.080287	-.021655
acreown	-.0010265	.002808	-0.37	0.715	5.25224	-.00653	.004477
edu2	.0651635	.037569	1.71	0.088	.400279	-.00847	.138797
edu3	.1500748	.0396081	3.67	0.000	.429568	.072444	.227705
ext1	-.0118217	.0301947	-0.39	0.695	.462343	-.071002	.047359
ext2	.0656366	.0364387	1.70	0.089	.179219	-.005782	.137055
hhmember	-.0077866	.0060884	-1.28	0.201	6.98954	-.01972	.004146
am	.0221729	.0512089	0.44	0.660	.85007	-.078195	.12254
ampres	.0503438	.0752058	0.70	0.486	.933752	-.097057	.197744
pct616	.001548	.0010258	1.51	0.132	32.5015	-.000463	.003558
pct40p	.000229	.0010249	0.22	0.823	21.7897	-.00178	.002238
pct1739	.0009639	.0011387	0.85	0.398	33.927	-.001268	.003196
pmaize	.0739411	.0142766	5.30	0.000	11.7197	.04596	.101923
nz1	-.4651865	.0706371	-6.21	0.000	.055788	-.603633	-.32674
nz2	-.6528248	.0524807	-8.83	0.000	.105997	-.755685	-.549964
nz3	-.5523172	.0549478	-8.86	0.000	.131102	-.660013	-.444622
nz5	.2226104	.0333833	5.31	0.000	.260112	.15718	.28804
nz6	.0019384	.0530116	0.04	0.971	.108089	-.101962	.105839
nz8	-.0451282	.0646823	-0.72	0.474	.220363	-.171903	.081647

Table 5. Tobit Regression on Determinants of Fertilizer Use

Tobit Estimates					Number of obs = 1281 chi2 (37) = 720.33 Prob > chi2 = 0.0000	
Log Likelihood = -3997.8767					Pseudo R2 = 0.0826	
fert	Coef.	Std. Err.	t	P>| t |	[95% Conf.	Interval]
fertkm	-.3741082	.1612025	-2.321	0.020	-.690367	-.0578493
pdap	-.1546073	.0381876	-4.049	0.000	-.2295265	-.0796881
hybrid	19.39249	6.596026	2.940	0.003	6.451927	32.33305
nz1hyb	-13.68411	22.24424	-0.615	0.539	-57.32447	29.95625
nz2hyb	-23.10646	9.892935	-2.336	0.020	-42.51514	-3.697784
nz3hyb	-7.435544	17.74057	-0.419	0.675	-42.24029	27.3692
nz5hyb	-.729031	10.85218	-0.067	0.946	-22.01962	20.56156
nz6hyb	-2.480823	8.857555	-0.280	0.779	-19.85822	14.89657
nz8hyb	-12.11443	8.610701	-1.407	0.160	-29.00753	4.778674
asset	3.84e-06	3.93e-06	0.978	0.328	-3.86e-06	.0000115
acreown	.1231422	.137127	0.898	0.369	-.1458836	.3921679
edu2	3.675489	2.934517	1.253	0.211	-2.081661	9.432638
edu3	6.200083	2.989465	2.074	0.038	.3351335	12.06503
ext1	5.638845	2.081353	2.709	0.007	1.555496	9.722194
ext2	6.934451	2.545455	2.724	0.007	1.940592	11.92831
hhmember	-.5716611	.4073685	-1.403	0.161	-1.370866	.2275439
am	-3.122632	3.419711	-0.913	0.361	-9.83167	3.586406
ampres	.2755076	5.02321	0.055	0.956	-9.579391	10.13041
pct616	-.0013921	.0697727	-0.020	0.984	-.1382772	.135493
pct40p	.0133077	.0718673	0.185	0.853	-.1276867	.1543021
pct1739	-.0179243	.0759453	-0.236	0.813	-.1669193	.1310708
pmaize	14.79877	6.115073	2.420	0.016	2.80177	26.79576
nz1pmz	-10.54789	7.422306	-1.421	0.156	-25.10951	4.01373
nz2pmz	-10.6378	6.534706	-1.628	0.104	-23.45806	2.182462
nz3pmz	-24.53945	28.7901	-0.852	0.394	-81.02196	31.94305

Tobit Estimates						Number of obs = 1281
						chi2 (37) = 720.33
						Prob > chi2 = 0.0000
Log Likelihood = -3997.8767						Pseudo R2 = 0.0826
fert	Coef.	Std. Err.	t	P>| t |	[95% Conf.	Interval]
nz5pmz	-1.924957	10.18893	-0.189	0.850	-21.91435	18.06444
nz6pmz	4.50111	9.792473	0.460	0.646	-14.71048	23.7127
nz8pmz	-23.06161	6.958427	-3.314	0.001	-36.71315	-9.410059
nz2	-30.95505	123.0337	-0.252	0.801	-272.3314	210.4214
nz3	251.1087	330.0416	0.761	0.447	-396.3908	898.6082
nz5	26.57095	4.777386	5.562	0.000	17.19833	35.94357
nz8	-70.39005	127.0177	-0.554	0.580	-319.5825	178.8024
nz1pdap	.0404766	.0732511	0.553	0.581	-.1032328	.1841859
nz2pdap	.089685	.0818375	1.096	0.273	-.0708698	.2502399
nz6pdap	-.0365053	.0779686	-0.468	0.640	-.1894697	.1164591
nz5pdap	.0140686	.0800336	0.176	0.860	-.1429472	.1710844
nz8pdap	.2678414	.0588416	4.552	0.000	.1524017	.3832811
_cons	39.54722	81.54903	0.485	0.628	-120.4416	199.536

3.3. Determinants of Maize Productivity

Table 6 present results of the two-stage least square model on maize productivity. The results indicate that there is no significant scale effect on maize productivity. In other words, farmers with larger farms within the sample are no more productive than those with smaller farms. In Gerhart's (1975) study in western Kenya, large farmers were found to adopt more hybrids and fertilizer, and to be more productive. But Hassan and Karanja (1997) found that large and smallholder farmers adopted hybrid maize in almost equal proportions. However, the latter lagged on fertilizer adoption and were, consequently, less productive. This study has found no scale effect on hybrid and fertilizer adoption, as well as productivity.

Table 6. Two-Stage Least Square Regression on Maize Productivity

Source	SS	df	MS
Model	2.1656e+10	21	1.0312e+09
Residual	1.1287e+11	1236	91320144.7
Total	1.3453e+11	1257	107022801

(2SLS)
Number of obs = 1258
F (21, 1236) = 8.60
Prob > F = 0.0000
R-squared = 0.1610
Adj R-squared = 0.1467
Root MSE = 9556.2

Value	Coef.	Std. Err.	t	P> | t |	[95% Conf. Interval]	
fert	164.3445	57.57082	2.855	0.004	51.39714	277.2918
hybrid	736.5173	1663.019	0.443	0.658	-2526.135	3999.17
asset	.001127	.0013474	0.836	0.403	-.0015165	.0037706
road	-683.8512	304.1422	-2.248	0.025	-1280.543	-87.15925
acreown	-11.3223	43.64741	-0.259	0.795	-96.9535	74.3089
edu2	581.1061	873.9358	0.665	0.506	-1133.456	2295.668
edu3	1385.534	914.2027	1.516	0.130	-408.0272	3179.094
ext1	313.1254	648.0276	0.483	0.629	-958.2303	1584.481
ext2	-1414.91	801.3945	-1.766	0.078	-2987.154	157.3335
hhmember	16.224	124.1132	0.131	0.896	-227.2719	259.7199
am	1724.663	1020.438	1.690	0.091	-277.319	3726.645
ampres	222.0241	1488.433	0.149	0.881	-2698.111	3142.159
pct616	-34.06435	21.38382	-1.593	0.111	-76.01696	7.888254
pct40p	-30.24119	21.46237	-1.409	0.159	-72.3479	11.86552
pct1739	-40.62754	23.23495	-1.749	0.081	-86.21183	4.956754
nz1	206.1318	1946.981	0.106	0.916	-3613.622	4025.885
nz2	2066.856	1295.756	1.595	0.111	-475.2677	4608.979
nz3	3457.564	1431.691	2.415	0.016	648.7508	6266.378
nz5	3599.947	1218.676	2.954	0.003	1209.044	5990.85
nz6	1671.409	1163.565	1.436	0.151	-611.3714	3954.19
nz8	2446.335	1088.598	2.247	0.025	310.6306	4582.039
_cons	5065.658	2278.292	2.223	0.026	595.9104	9535.406

The results indicate that fertilizer use has a statistically significant and strong effect on productivity. After considering mean fertilizer and maize prices prevailing during 1997, the year of the survey, the mean value-cost ratio for fertilizer use is calculated at 5.86. This means that for every Ksh spent on fertilizer (DAP), the farmer gets 5.86 Kshs cash-back in value of output. Although the direct impact of hybrid on productivity is large but not significant, when combined with its large and significant influence on use of fertilizer, the overall effect becomes significant. The distance from motorable road is inversely related to productivity, indicating that farmers closer to roads tend to generate higher levels of productivity, other factors held constant. The major influence here is likely to be through the access to markets and lower transport costs. Households with more highly educated members also have more productive levels of maize output per unit of area. The results also point to the importance of agricultural extension. When the direct and indirect effects are taken into account, farmers who received extension contact in the past 1-2 years were more productive than those who received contact 3-5 years back. The latter has a net negative effect. Households with both male and female present were found to be more productive than where the male was not present on-farm. This may be related to access to farm credit, in which males have better access. However, unlike in the variety choice model, the value of assets did not have a direct significant influence on productivity. Among the agro-regional zones, the Central Highlands, Western Highlands and the High potential zones had a positive and significant difference in productivity from the Western Transitional zone and the rest of the lowlands.

4. IMPACT OF MAIZE MARKET LIBERALIZATION

One of the most important and debated issues in Kenyan food policy discussions has been the effects of food market liberalization. One viewpoint holds that liberalization has been associated with a cutback in support to smallholder farmers. Evidence in support of this view is that the NCPB has closed many rural grain depots since the reform process began, as part of tightening fiscal constraint under structural adjustment. The argument is that the withdrawal of NCPB market infrastructure cut off farmers from grain sale outlets and forced them to face lower and more unstable output prices in local markets or at farm gate. However, as indicated earlier, there was the perception that market reforms would lead to better producer prices and access to inputs by farmers. For more discussion of some of these perceptions see Jayne et al. (1998).

Table 7 presents descriptive data on the levels and variability of maize prices in various markets over the sample period. For most markets reported, there was a progressive decline in the inflation-adjusted maize price between the control period and the Phase 2 period of liberalization. The price decline was especially pronounced in the maize deficit areas of Nairobi, Kisumu, and Nyeri, where wholesale prices have declined 34% on average between the control period and Phase 2 liberalization period. By contrast, prices declined by an average of 17% over the same period in the generally surplus markets of Kitale, Eldoret, Kisii and Nakuru. This suggests that price spreads between the surplus and deficit areas may have narrowed somewhat after liberalization. While the NCPB producer price was on average lower than most market prices during the control period, this has shifted since market reforms. However, it is difficult to make meaningful comparisons between NCPB prices and market

Table 7. Maize Prices and Standard Deviations in Selected Markets[1]

	Control Period (1985.1 - 1988.4)	Reform Phase 1 (1989.1 - 1993.4)	Reform Phase 2 (1994.1 - 1998.3)
NCPB Price	919 (54)	826 (130)	1051 (31)
Eldoret	1399 (246)	1181 (319)	1022 (346)
Kitale	1140 (205)	1069 (233)	956 (319)
Kisii	1219 (219)	1092 (214)	942 (313)
Nakuru	937 (208)	1030 (314)	964 (294)
Kisumu	1581 (144)	1424 (290)	1149 (338)
Meru	1349 (285)	1102 (353)	1122 (293)
Nyeri	1730 (367)	1280 (191)	1094 (294)
Nairobi	1593 (252)	1346 (201)	1164 (260)

Sources: Market Information Bureau, Ministry of Agriculture; Consumer price inflation data from IMF Financial Statistics.
[1] Constant 1997 Ksh/90-kg bag (Standard deviations in parentheses).

prices in the Phase 2 period as the NCPB's role in the market declined to marginal proportions since 1995.

The market reform process has also been associated with more variable prices than the NCPB's pan-seasonal, pan-territorial prices during the control period. While unconditional price variances in local markets have generally increased, some of the variability is predictable and in fact necessary to induce useful marketing functions by the private sector. For instance, seasonal price increases are necessary to encourage on-farm and off-farm storage during the season, an area that was deeply neglected and even found unnecessary during the control period. However, the extent to which the unpredictable component of maize prices, that is the conditional variance in prices, has increased in Kenya after market reform is unclear, and is a useful subject of future research.

Results of the SUR model of reform impact on price levels are presented in Table 8. The adjusted R-squared values for each of the regressions are in the range between 0.36 and 0.76. The results indicate strong seasonal effects in most markets, and differences in seasonal high and low price periods. Rainfall effects are significantly negative, as expected, in a few cases.

Table 8. Seemingly Unrelated Regression Results by Selected Markets

	Eldoret	Kisii	Kitale	Nakuru	Meru	Nyeri	Kisumu	Nairobi
Constant	**1044.5 *** **	131.7	**729.2 *** **	**652.5 *** **	**661.4 *** **	**519.3 *** **	376.8	**760.2 *** **
1st quarter	-50.7	**229.6 *** **	93.4	57.3	-28.6	64.2	126.2	9.2
2nd quarter	71.1	34.7	**165.2 ** **	67.9	**163.4 ** **	**177.3 *** **	-54.3	72.6
3rd quarter	**-293.4 *** **	**161.4 *** **	**-173.6 ** **	-76.2	90.7	63.0	-136.5	39.8
Rainfall	-0.23	**0.18 * **	-0.04	**-0.33 ** **	-0.10	**-0.18 * **	0.25	-0.09
Reform Phase 1	**-169 ** **	-42.8	-67.1	**91.6 * **	**-103.2 * **	-36.3	-156.4	**-94.0 ** **
Reform Phase 2	**-219 *** **	-87.3	**-103.8 * **	61.7	-36.1	-50.4	**-253.2 ** **	**-163.2 *** **
P_{t-1}	**0.38 *** **	**0.46 *** **	**0.38 ** **	**0.57 *** **	**0.53 *** **	**0.69 *** **	**0.45 *** **	**0.46 ** **
P_{t-2}	–	-0.12	--	--	-0.23	--	--	--
Adjusted R^2	0.38	0.37	0.34	0.57	0.44	0.76	0.46	0.49
DW	1.87	1.66	1.92	1.99	1.56	1.89	1.71	1.59

This suggests that maize prices in some areas are less affected by local rainfall conditions compared to other factors.

Regarding the effects of the price changes due to market reform, at least one of the two reform coefficients was statistically significant at least at the 10% level in 6 of 8 selected markets. The Phase 1 reform variable was negative in 7 of 8 cases and significantly in only 4 cases. During Phase 2, which is the more important of the two reform periods, the effect on maize price was, again, negative in 7 of the 8 markets and again significantly in 4 cases. However, the magnitude of effect was larger in Phase 2 than during Phase 1. Across all 8 markets, the mean change in the wholesale maize price was -98.7 Ksh per 90 kg bag. This represented an 8% decline in maize price levels, on average, due to market reform after controlling for other factors represented in the model. For particular markets, the percentage change in price levels associated with the Phase 2 reforms ranged from -16.0% in Kisumu to +6.5% in Nakuru.

Based on these estimated price changes for each market (and matching them to particular regions in the household survey), the following price changes (in parentheses) were simulated: Coastal Lowlands, Eastern Lowlands and Western Lowlands (-10%); Western Transitional and Western Highlands (-8%); High-Potential Maize Zone (-12%); and Central Highlands (-4%). These were then used to estimate the impact of price changes on maize productivity.

All of the relevant coefficients in these three pathways mentioned in Section 3 were statistically significant at least at the 10% level, except for the impact of hybrid seed use on maize productivity (see Tables 4, 5 and 6). Thus, only the first and third hypothesized pathways had statistically significant effect according to the model results. The combination of these effects are aggregated and presented in Table 9. From Table 4 on the Probit and Table 5 on the Tobit regression results, there were notable zonal differences in some of the measured effects due to the significance of some zonal interaction terms, for example, the effect of maize price on fertilizer use. These statistically significant differentials were also taken into account in the derivation of the final simulated results. The results in Table 9 indicate that, on average, impact of market reforms through the price effect had a negative effect on fertilizer use and hence retarded maize productivity. This effect varied by agro-regional zone. The effect ranged between +2.2% in the Central Highlands to -12.3% in the Western Transitional Zone. The impact on productivity in the highlands averaged -10% whereas in the lowlands it was much lower. This is because the effect of price was transmitted mainly through the effect on fertilizer use and the lowlands are relatively low users of fertilizers (Table 1).

However, the overall effect of market liberalization must be weighed against all other possible effects and macro-objectives of the reform process, which include keeping consumer prices low, reducing the burden to the exchequer of maize trading, improving flows of maize between surplus and deficit regions, increasing private sector participation in the maize market and providing adequate incentives to producers. Using the same household data set as in this study, Jayne et al. (1998) report that a large majority of farmers in Kenya feel that higher maize prices are not necessarily in their best interests. Farmers in deficit regions, for example, who tend to be net buyers of maize, indicated that their welfare is enhanced by lower maize prices. Nationally, on average, two-thirds of all sampled farmers echoed this sentiment while 61% of the total were net buyers. Over 60% of the farmers surveyed felt grain was more

Table 9. Simulation of the Effect of Changes in Maize Prices on Maize Productivity

	Baseline Maize Productivity (Ksh/Acre)	Baseline Fertilizer Nutrient Use (Kgs/Acre)	Simulated Change in Maize Productivity Ksh/Acre (% change)
Coastal Lowlands	5,735	0.18	-115 (-2.0%)
Eastern Lowlands	5,506	1.50	-368 (-6.7%)
Western Lowlands	5,996	0.15	-53.3 (-0.9%)
Western Transitional	7,015	13.60	-866 (-12.3%)
High-Potential Zone	13,576	31.59	-1,087 (-8.0%)
Western Highlands	8,173	16.07	-792 (-9.7%)
Central Highlands	10,946	23.38	+238 (+2.2%)
Average	**9,543**	**16.91**	

available for purchase under liberalized markets than during the control period. Also, 88% of the farm households surveyed felt that it was easier to sell grain now than before while, in general, 61% preferred the current market set up compared to 34% who preferred the controlled market system. These contradict many perceived expressions, sometimes even in policy circles. Further evidence indicate that, for example, access to key inputs may have improved due to private sector entry as the food and input system has become liberalized. Such effects do not necessarily operate directly through price, but rather through accessibility. Hence, an important caveat of this study is that it measures only one potential pathway by which liberalization may have affected farm input decisions and productivity levels, and one policy objective which needs to be considered in the backdrop of a myriad of other viable policies such as improving consumer food security and access, nutrition and shifts to higher valued crops. However, the results do indicate that the decline in real maize prices attributable to the market reforms has adversely affected fertilizer use on maize area, with relatively small but significant effects on the value of output produced per unit of cultivated land.

5. CONCLUSION

The objective of this study was two pronged: (1) to determine factors influencing farm-level maize productivity; and (2) to assess the impact of maize market reforms on productivity. On the second objective, this study only focused on the impact of maize price changes attributed to the reforms on maize productivity. Using a probit regression model, the results indicated that value of farm assets, favorable maize output price, higher human capital within the farm household and extension contact positively influenced the likelihood of adoption of hybrid maize whereas this declined with distance to motorable roads. However, there was no scale effect on hybrid adoption probably due to the fact that the study was mainly based on a sample of smallholder farmers. On the other hand, the intensity of fertilizer use was positively influenced by use of hybrid seed, proximity to fertilizer market, education, extension contact and price of maize. As in the case of hybrid maize, there was no scale effect on fertilizer use. However, a value-cost analysis found that one shilling investment in fertilizer use on maize raised 5.86 shillings worth of maize output.

Maize productivity increased with fertilizer use, proximity to motorable roads, education, extension and presence of male in the household. This underscores the importance of improving the seemingly deteriorating road infrastructure and investing in human capital and extension. The impact of extension on productivity operated through several pathways. After controlling for other factors, extension was found to increase both hybrid seed and fertilizer use and, hence, promote productivity growth. In all the models, the effects on input use and maize productivity varied significantly by agro-regional zones. However, there was a considerable intra-zonal variation in productivity which was higher than the mean difference inter-zonal productivity. This revealed a great potential for overall productivity growth if the level of productivity of the lower half of the farmers could be elevated to at least the mean level within each zone. This is considered possible since there are already farmers who are achieving such levels of productivity (within each zone, therefore holding agro-ecological potential constant). Achieving these gains among the low-productivity farmers will require additional extension and demonstration activities so that the management practices of the high-yielders within particular areas can be replicated more widely throughout the community.

The effect of market liberalization was traced through simulation of its impact on maize prices and, consequently, the effect of these prices on input use on maize. This study found that, on average, maize market reforms led to decreases in maize prices and subsequent negative effect on input use and maize productivity in almost all agro-regional zones. This effect varied by agro-regional zone and ranged between +2.2% in the Central Highlands to -12.3% in the Western Transitional Zone. The impact on productivity in the highlands averaged -10% whereas in the lowlands it was much lower. This is because the effect of price was transmitted mainly through the effect on fertilizer use and the lowlands are relatively low users of fertilizers.

However, the overall impact of market liberalization must be weighed against all other possible effects and macro-objectives of the reform process, which include keeping consumer prices low for consumers, reducing the burden to the exchequer of maize trading, improving flows of maize between surplus and deficit regions, increasing private sector participation in the maize market and providing adequate incentives to producers. It is beyond the scope of this study to make any comprehensive conclusions about the overall effects of maize market reform on welfare, but we consider it important to shed light on certain partial, albeit important, effects, e.g, the effect of price changes resulting from the reform process on maize productivity. The findings imply the need to find ways to reduce the costs of input distribution and farm production through technological and institutional innovation in order to make input intensification increasingly profitable despite falling output prices.

6. REFERENCES

Barker, R. and R.W. Herdt. 1978. Equity Implication of Technology Changes. In *Interpretive Analysis of Selected Papers from Changes in Rice Farming in Selected Areas of Asia*. Los Banos: International Rice Research Institute.

Byerlee, D. and C.K. Eicher. 1997. Africa's Food Crisis. In *Africa's Emerging Maize Revolution*, eds. D. Byerlee and C.K. Eicher. Boulder: Lynne Rienner Publishers.

Duraisamy, P. 1989. *Human Capital and Adoption of Innovations in Agricultural Production: Indian Evidence*. Discussion Paper No. 577. New Haven, Connecticut: Yale University Economic Growth Center.

Evenson, Robert. 1981. Benefits and Obstacles to Appropriate Agricultural Technology. *Annals of the American Academy of Political and Social Science* 458: 54-67.

Feder, G. and D.L. Umali. 1993. Adoption of Agricultural Innovations: A Review. *Technology Forecasting and Social Change* 43(3/4): 215-39.

Gerhart, J. 1975. *The Diffusion of Hybrid Maize in Western Kenya*. Mexico City, D.F.: Centro Internacional de Mejoramiento de Maiz y Trigo (CIMMYT).

Hassan, R.M. and D.D. Karanja. 1997. Increasing Maize Production in Kenya: Technology, Institutions and Policy. In *Africa's Emerging Maize Revolution*, eds. D. Byerlee and C.K. Eicher. Boulder: Lynne Rienner Publishers.

Heckman, J. 1979. Sample Selection Bias as a Specification Error. *Econometrica* 47(1): 153-161.

Hicks, W.H. and R. Johnson. 1974. *Population Growth and the Adoption of New Technology in Taiwanese Agriculture*. Working Paper in Economics No. 1974-E6. Columbia: University of Missouri.

Jamison, D.T. and L.J. Lau. 1982. *Farmer Education and Farm Efficiency*. Baltimore: Johns Hopkins University Press.

Jayne, T.S., G.A. Kodhek, G. Nyambane, and T. Yamano. 1998. Baseline Characteristics of Smallholder Agriculture and Non-Farm Activities for Selected Districts in Kenya. Paper presented at the Conference on Strategies for Raising Smallholder Agricultural Productivity and Welfare, Egerton University/Tegemeo Institute of Agricultural Policy and Development, November 24, Nairobi, Kenya.

Karanja, D.D. 1990. The Rate of Return to Maize Research in Kenya: 1955-88. M.S. thesis, Michigan State University.

Karanja, D.D. 1996. *An Institutional and Economic Analysis of Maize Research in Kenya*. MSU International Development Working Paper. No. 57. East Lansing: Michigan State University.

Lipton, M. 1976. Agricultural Finance and Rural Credit in Poor Countries. *World Development* 4 (July): 543-54.

Lowdermilk, M. 1972. Diffusion of Dwarf Wheat Production Technology in Pakistan's Punjab. Ph.D. dissertation, Cornell University.

Maddala, G.S. 1983. *Limited Dependent and Qualitative Variables in Econometrics*. London: Cambridge University Press.

Mose, L.O. 1997. An Economic Analysis of the Determinants of Fertilizer Use in Small Maize Farms in Western Kenya. Msc. thesis, University of Nairobi.

Muturi, W. M. 1989. Factors Influencing the Use of Fertilizers among Smallholder Farmers. A Case of Muranga District. MA thesis, University of Nairobi.

Mwangi, W. M. 1978. Farm Level Derived Demand Responses for Fertilizers in Kenya. Ph.D. thesis, Michigan State University.

Omamo, S.W. 1998. Transport Costs and Smallholder Cropping Choices: An Application to Siaya District, Kenya. *American Journal of Agricultural Economics* 80 (February): 116-123.

Ongaro, W.A. 1988. Adoption of New Farming Technology. A Case Study of Maize Production in Western Kenya. Ph.D. thesis, University of Gothenburg.

Parthasarathy, G. and D.S. Prasad. 1978. *Response to the Impact of New Rice Technology by Farm Size and Tenure: Andhra Pradesh, India*. Los Banos: International Rice Research Institute.

Rahm, M.R. and W.E. Huffman. 1984. The Adoption of Reduced Tillage: The Role of Human Capital and Other Variables. *American Journal of Agricultural Economics* 66(4): 405-413.

Rosenzweig, M.R. 1978. Schooling, Allocative Ability and the Green Revolution. Paper presented in a meeting of the Eastern Economic Association, Washington, D.C.

Ruttan, V. 1977. The Green Revolution: Seven Generalizations. *International Development Review* 19 (December): 16-23.

Schluter, M. 1971. *Differential Rates of Adoption of the New Seed Varieties in India: The Problem of the Small Farm*. United State Agency for International Development

(USAID) Occasional No. 47. Ithaca, New York: Cornell University.

Schutjer, W. and M. Van der Veen. 1977. *Economic Constraints on Agricultural Technology Adoption in Developing Countries*. United States Agency for International Development (USAID) Occasional Paper No. 5. Washington, D.C.: USAID.

Sharma, A.C. 1973. Influence of Certain Economic and Technological Factors on the Distribution of Cropped Area Under Various Crops in the Ludhiana District. *Journal of Research* (Punjab Agricultural University) 10 (June): 243-49.

Strauss, J., M. Barbosa, S. Teixeira, D. Thomas, and R.D. Junior. 1991. The Role of Education and Extension in the Adoption of Technology: A Study of Upland Rice and Soybean Farmers in Central-West Brazil. *Agricultural Economics* 5: 341-359.