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Welfare effects of maize technologies in marginal and high potential regions of Kenya

D.D. Karanja[a], M. Renkow[b,*], E.W. Crawford[c]

[a] Bread for the World, Washington, DC, USA
[b] Department of Agriculture and Resource Economics, North Carolina State University, Raleigh, NC 27695-8109, USA
[c] Department of Agricultural Economics, Michigan University, East Lansing, MI, USA

Abstract

This paper describes the findings of a study that used a multi-market model to assess the potential impact of improved maize technologies on the welfare of various types of rural and urban households in Kenya. The modelling results indicate that technologies developed for high potential regions are likely to have more profound aggregate impacts on maize production and lead to greater reductions in import demand (if prices are controlled) or maize prices (if maize prices are flexible). Technology adoption in high potential regions is likely to have substantially greater positive impacts on aggregate real incomes, but inferior income distributional outcomes compared to technology adoption in marginal regions.
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1. Introduction

A long-standing debate within national and international agricultural research systems revolves around distributional impacts of different allocations of research effort between marginal and high potential production environments. Some argue that there is systematic under-investment in marginal production environments, to the detriment of the large group of impoverished people within those areas (Fan and Hazell, 1999; Hazell and Garrett, 1996). Others counter that investment in marginal areas historically has been low because returns to those investments are low, and that diverting research resources away from high potential production environments would do more harm than good (Coxhead and Warr, 1991; Renkow, 2000).

In Kenya, this debate is critically important for several reasons. Agriculture is the dominant sector in the economy, accounting for 28–30% of GDP. The country's rapid population growth has put considerable pressure on its limited arable land. This has resulted in out-migration of people from regions of high agronomic potential to more marginal agronomic regions, which poses great challenges to agricultural research and environmental sustainability.

The spatial transformation of agricultural production has received increasing attention in Kenya's recent development programming, including promises for greater resource allocation to marginal regions. But a general worsening of the economy, along with a decline in agricultural productivity over the past decade, has heightened the debate on whether to invest scarce research resources in high potential or marginal regions to obtain the greatest potential

* Corresponding author. Tel.: +1-919-515-5179; fax: +1-919-515-6268.
E-mail address: mitch_renkow@ncsu.edu (M. Renkow).

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benefits. This study contributes to this debate by developing empirical insights into the impacts of regionally differentiated maize technology adoption on aggregate incomes and income distribution.

Maize is by far the most important crop grown in Kenya in terms of total value added in agriculture, and share in total production and consumption. Kenya's agricultural research institute, KARI (previously known as the Scientific Research Division of the Ministry of Agriculture), is credited with having developed many promising maize production technologies suited for the various agro-ecological zones in the country, which have fuelled past increases in maize production.

However, recent trends indicate that maize productivity growth is declining and that there is a wide yield gap between experiment station and farmers' yields which can be exploited for productivity gains (Karanja, 1996; Hassan and Karanja, 1997). Recent setbacks in Kenya's maize sector—including the effects of bad weather, dislocations associated with adjustment to market reforms, and credit and extension institutional collapses—have caused many maize technologies to remain unexploited or 'on the shelf', even though they embody important plant genetic and crop management improvements.

This study carries out an *ex ante* evaluation of the impacts that adoption of these technologies is likely to have on different households located in different agro-ecological zones. We employ a multi-market model similar to that used by Renkow (1993) to compute both absolute and relative welfare effects of technological change on different household types located in six distinct agro-ecological zones and in urban areas. Particular attention is paid to alternative technology adoption scenarios in which diffusion is confined to either high potential or marginal production regions. We find that the aggregate income effects are greatest when technological change occurs in high potential zones, but that technology adoption in marginal zones leads to superior income distributional outcomes.

The paper is laid out as follows. The next section describes the multi-market model on which the empirical analysis is based. Following this is a discussion of the data used to implement the model. The empirical results are then presented, followed by a discussion of the results and implications of the findings for future research and policy.

2. Analytical framework

The multi-market model used in this study is similar to that used by Renkow (1993) to assess the welfare effects of regionally differentiated technological change in Pakistan. It is a richer model than its predecessor, however, in that it uses a more disaggregated delineation of geo-referenced, agro-ecological zones.[1] The model features a system of equations that characterise the economic behaviour of 13 different household types: small farms and large farms in each of Kenya's six agro-ecological zones plus urban households. Based on agro-climatic characteristics and suitability for maize production, four of the agro-ecological zones (Lowlands, Dry Mid-altitude, Moist Mid-altitude and Dry Transition) are delineated as marginal regions, and the other two zones (Moist Transition and Highlands) are delineated as high potential zones (Table 1).

Households in each production zone are assumed to produce two commodities (maize, Q_1, and one 'other' crop, Q_2) using two variable inputs (labour, L, and fertiliser, F). The technology shifter, E, is modelled as an exogenous variable that shifts out both the supply of maize and the demand for the variable inputs. Land is considered as the only fixed input. Therefore, household output supplies and input demands depend on the prices of the two commodities (P_1 and P_2), the prices of the variable inputs (w and f) and, except for Q_2, the technology shifter. The respective output supply and input demand equations, in rate-of-change notation,[2] are as follows:

$$\hat{Q}_{1h} = \varepsilon_{11h}\hat{P}_1+\varepsilon_{12h}\hat{P}_2+\varepsilon_{1Lh}\hat{W} + \varepsilon_{1Fh}\hat{f}+\hat{E}_{1h} \quad (1)$$

$$\hat{Q}_{2h} = \varepsilon_{21h}\hat{P}_1 + \varepsilon_{22h}\hat{P}_2 + \varepsilon_{2Lh}\hat{W} + \varepsilon_{2Fh}\hat{f} \quad (2)$$

$$\hat{L}_h^{\mathrm{D}} = \beta_{L1h}\hat{P}_1+\beta_{L2h}\hat{P}_2+\beta_{LLh}\hat{W}+\beta_{LFh}\hat{f}+\hat{E}_{Lh} \quad (3)$$

$$\hat{F}_h = \beta_{F1h}\hat{P}_1+\beta_{F2h}\hat{P}_2+\beta_{FLh}\hat{W}+\beta_{FFh}\hat{f}+\hat{E}_{Fh} \quad (4)$$

[1] Multi-market models such as this one additionally allow analysis of distributional outcomes across a broader array of household types than is afforded by economic surplus models, particularly in the context of semi-subsistence producers.

[2] As is standard in these models, general functional forms, e.g., $Q_{1h} = f(P_1, P_2, w, f, E_{1h})$, are converted to rate-of-change form by taking log differentials. Due to space limitations, we only present the log-differential forms.

Table 1
Basic demographic and maize production characteristics of Kenya's agro-ecological zones[a]

Variable	Marginal regions				High potential regions		All zones
	Lowlands	Dry mid-altitude	Moist mid-altitude	Dry transition	Moist transition	Highlands	
Total number of agricultural households							
Small farm	112000	469000	639000	153000	992000	628000	2992000
Large farm	24000	107000	62000	30000	107000	88000	418000
Population (% of total)[b]							
Small farm	3.4	11.9	11.9	4.5	19.4	11.2	62.3
Large farm	0.7	2.7	1.1	0.9	3.2	3.6	12.2
Maize production, 1992–1998							
Maize output (t)	39700	245100	377000	136400	1076000	686100	2560700
Maize area (ha)	44800	331400	190000	121700	441000	331300	1440200
Maize yield (t/ha)	0.89	0.74	1.98	1.12	2.44	2.20	1.78

[a] Source: Karanja (2002).
[b] This ignores people living in urban areas (22.4% of the total population) and people living in non-maize producing areas (3.1% of the total population).

where ^ denotes proportional rates of change (i.e., $\hat{x} = \mathrm{d}\ln x$); ε_{ik} and β_{jk} are elasticities of output i or input j with respect to price k ($k = P_1, P_2, W, f$); $\hat{E}_k$ is the exogenous proportional shift in output supply or input demand due to the new technology holding fixed inputs constant; and the subscript h denotes household type (e.g., small farm households in the Highlands zone).

It is assumed that all residual farm profits not attributed to variable inputs accrue as returns to land. Changes in farm profits (Π) are given by

$$\hat{\Pi} = \pi_1(\hat{P}_1 + \hat{Q}_1) + \pi_2(\hat{P}_2 + \hat{Q}_2) + \pi_L(\hat{W} + \hat{L}^{\mathrm{D}}) + \pi_F(\hat{f} + \hat{F}) \quad (5)$$

where π_i's are household-specific profit shares accounted for by outputs and variable inputs (positive for outputs and negative for inputs).

It is assumed that two commodities are consumed—maize and an alternate commodity (A). Household demands (indicated by a lower case c) are taken to be functions of the prices of these commodities and nominal income (Y): $c_k = c_k(P_1, P_A, Y)$ for $k = 1, A$. Consumption of all households of a particular type (C_h) is simply the product of household demand and the population of that type of household (N_h), i.e., $C_{kh} = c_{kh}N_h$. Changes in consumption for all household of a particular type are thus given by

$$\hat{C}_{1h} = \eta_{11h}\hat{P}_1 + \eta_{1Ah}\hat{P}_A + \eta_{1Yh}\hat{Y}_h + \hat{N}_h \quad (6)$$

$$\hat{C}_{Ah} = \eta_{A1h}\hat{P}_1 + \eta_{AAh}\hat{P}_A + \eta_{AYh}\hat{Y}_h + \hat{N}_h \quad (7)$$

where η_{ijh} is the elasticity of demand for commodity i with respect to j ($j = 1, A, Y$) for household type h.

Household labour supply (l^{s}) is assumed to be a function of the real wage $w = W/P_h^*$, where P_h^* is an endogenous, household-specific price index, i.e., $l^{\mathrm{s}} = l^{\mathrm{s}}(w)$. Thus, labour supply for a particular household type is simply $L_h^{\mathrm{s}} = l_h^{\mathrm{s}} \times N_h$. Letting ε_{Lh} be the wage rate elasticity of household labour supply, proportional changes in labour supply are given by

$$\hat{L}_h^{\mathrm{s}} = \varepsilon_{Lh}\hat{w} + \hat{N}_h \quad (8)$$

Nominal household income is the sum of the returns to all factors rented out by the household, including labour income, farm profits and other exogenous sources (X), such as non-agricultural labour: $Y = WL^{\mathrm{s}} + \Pi + X$. Letting μ_{kh} denote the household-specific shares of income attributable to income source k ($k = L, \Pi, X$), changes in real income ($y = Y/P^*$) are given by

$$\hat{y}_h = \mu_{Lh}(\hat{W} + \hat{L}_h^{\mathrm{s}}) + \mu_{\Pi h}\hat{\Pi}_h + \mu_{Xh}\hat{X}_h - \hat{P}_h^* \quad (9)$$

Closing the model requires specification of the conditions under which the markets for maize and labour clear. As the interest here is to examine long-run effects of technological change, it is assumed that labour is sufficiently mobile over the long-run that wage rates are determined in a national labour market. The labour market clearing condition is thus

$$\sum_h \frac{L_h^{\mathrm{D}}}{L} \hat{L}_h^{\mathrm{D}} = \sum_h \frac{L_h^{\mathrm{s}}}{L} \hat{L}_h^{\mathrm{s}} \tag{10}$$

The market clearing condition for maize is based on the identity $C_1 = Q_1 + G$, where C_1 is the total national maize consumption, Q_1 the total national production and G the quantity of commodity 1 accounted for by government-influenced maize imports. Therefore, in rate-of-change notation, the market clearing identity becomes

$$\sum_h \frac{C_{1h}}{C_1} \hat{C}_{1h} = \sum_h \frac{Q_{1h}}{Q_1} \hat{Q}_{1h} + \Gamma \hat{G} \tag{11}$$

where $\Gamma = G/C_1$ is the share of imports in the national consumption.

Two variant solutions based on Eq. (11) are considered. Variant I assumes the maize price, P_1, is determined by the intersection of aggregate supply and demand curves for maize. Here, P_1 is endogenously determined and G is exogenous. In contrast, Variant II assumes that P_1 is exogenously determined by government price policy. In this case, G becomes endogenous; that is, imports are determined such that they make up for the excess demand or excess supply of commodity 1 implied by the exogenously determined price of maize.

The model can be expressed as $\mathbf{HU} = \mathbf{K}$, where $\mathbf{U}$ is an $n \times 1$ vector of proportional changes in endogenous variables, $\mathbf{K}$ is an $n \times 1$ vector of proportional changes in exogenous variables, and $\mathbf{H}$ is an $n \times n$ matrix of parameters (elasticities and shares). Inverting the $\mathbf{H}$ matrix and pre-multiplying both sides of the equation allow simulation of changes in endogenous variables due to 'shocks' reflected by changes in exogenous variables. Specifically, the model is used to investigate how prices, quantities, farm profits and household income change in response to alternative scenarios of diffusion of maize production technology packages.

3. Implementation

Two sets of model simulations were conducted. The first were based on the fixed-price model in which maize prices are determined exogenously (by government price policy or by the world market). In these simulations, endogenous maize imports bridge the gap between national demand and domestic production. This resembles the Kenyan maize market during the pre-1994 period when the government controlled maize marketing and pricing. The second set of simulations were based on the flexible-price model in which Kenyan maize prices are determined endogenously by domestic demand and supply conditions, but the government has potential influence on exogenous imports. These simulations mimic the current system in which the maize market is liberalised with respect to internal trade and the government influences maize trade by sanctioning maize imports.

Three types of data were required to run the models: (1) share parameters identifying the relative importance of various sub-components of households' production, consumption, agricultural profits and income; (2) estimates of likely changes in key exogenous variables (technology shifters and growth rates of exogenous income and population); and (3) elasticities governing household response to changes in prices and income.

3.1. Share data

Regional production and consumption shares were computed from aggregate statistics published by the Ministry of Agriculture's Department of Remote Sensing and Resource Surveys (DRSRS) and by Kenya's Central Bureau of Statistics. Household-level production consumption, profit and income shares were computed from household- and village-level data collected between June and October 1999 from a sample of 426 farmers in 30 population clusters located in the six maize agro-climatic zones (Karanja, 2002).[3]

Table 2 presents the key share parameters used to initialise the multi-market model. The regional maize production shares indicate that two-thirds of maize output comes from the high potential regions. Clearly,

[3] The sampling frame of this data collection effort was a subset of a much larger household survey conducted as part of the 1994 Kenya Maize Data Base project. That project used a GIS-referenced multi-stage stratified random sampling frame for a national survey of 1407 Kenyan maize farmers (see Hassan et al., 1998 for details).

Table 2
Key parameters used in the multi-market model

Variable	Marginal regions				High potential regions	
	Lowlands	Dry mid-altitude	Moist mid-altitude	Dry transition	Moist transition	Highlands
Maize production shares[a] (% of national total)						
Small farms	0.5	3.3	9.1	3.9	13.6	16.8
Large farms	0.7	4.4	5.8	0.5	27.1	11.2
Maize profit shares[b] (% of farm profits from maize)						
Small farms	6.9	16.0	39.6	22.9	34.2	33.5
Large farms	34.7	16.0	37.7	9.3	38.5	24.2
Farming income shares[b] (% of household income from farm profit)						
Small farms	42.1	68.8	40.7	57.8	53.1	74.8
Large farms	41.4	64.5	82.3	51.4	95.3	93.8
Labour income shares[b] (% of household income from agricultural labour)						
Small farms	10.1	15.4	21.2	13.7	9.2	6.4
Large farms	8.4	13.2	4.9	11.7	0.4	0.6
Maize expenditure shares[b] (% of household expenditure on maize)						
Small farms	29.0	15.7	24.1	11.7	11.2	12.8
Large farms	47.2	2.6	19.7	49.8	16.5	19.5

[a] Source: DRSRS (1999).
[b] Source: Karanja (2002).

factors that enhance maize yields in the high potential regions will have greater impacts on aggregate maize supply and, to the extent that it is determined by prevailing supply and demand conditions, the price of maize. Large farms account for a particularly large output share in the (high potential) Moist Transition zone; in nearly all other zones, smallholders account for equal or larger shares of zonal maize output.

All else being equal, an increase in maize profitability will affect more strongly households for whom the maize profit share represents a large proportion of household income. Table 2 indicates that profits from maize production range from being highly important for all households in the high potential zones and the (marginal) Moist Mid-altitude zone to being relatively insignificant for some households in marginal regions.

In addition to farm profits, rural households also obtain a sizeable fraction of total household income from the sale of surplus household agricultural labour. Therefore, factors that affect agricultural wage rates, such as shifts in labour demand attributable to diffusion of new labour-intensive technologies, may have important impacts on household well-being. Labour income shares vary widely across and within agro-ecological zones; they are invariably larger for small farm households than for large farm households, especially in the high potential regions and the (marginal) Moist Mid-altitude zone.

Finally, maize's dominance as a food staple is reflected in the data on expenditure shares. To the extent that shifts in maize supply lead to lower maize prices, the positive impact on real incomes of maize technology diffusion will be greater the larger are the household expenditure shares, as is the case for some household types in marginal regions.

3.2. Technology shifters

Table 3 presents the net yield gains and input demand shifts associated with the zone-specific technology packages currently on the shelf. These estimates come from Mills et al. (1998), who calculated these figures conditional upon specified adoption thresholds. These estimates were painstakingly assembled via surveys of stakeholder committees that included maize researchers, extension agents and farmers. Expert assessment of likely research impacts were generated by research themes (breeding, crop management and

Table 3
Net yield gains and input demands associated with zone-specific technologies[a]

	Source of yield gains (%)					
	Breeding	Crop management	Technology transfer	Net yield gain	Labour demand increase	Fertiliser demand increase
Marginal regions						
Lowlands	14	37	49	7.4	11.6	5
Dry mid-altitude	0	51	49	13.0	11.3	2
Moist mid-altitude	7	56	37	14.4	11.6	5
Dry transition	30	33	37	28.2	10.8	2
High potential regions						
Moist transition	64	6	30	29.7	5.9	6
Highlands	45	3	52	8.8	5.5	6

[a] Source: Mills et al. (1998).

technology transfer), as well as by the agro-climatic zones considered in this study.

Projected net yield gains are highest for the Moist Transition zone (29.7%) and smallest for the Lowlands zone (7%). Interestingly, the Highland zone—traditionally Kenya's dominant commercial maize growing area—has a low projected net yield gain (9%), traceable to relatively low expected additional breeding and crop management impacts. In general, yield gains in marginal regions are more attributable to changes in crop management practices (e.g., labour-intensive soil and water conserving technologies), whereas breeding research is projected to play a relatively more important role in the high potential regions. The implications of technology adoption for changes in labour demand is correspondingly higher in marginal zones.

3.3. Elasticities

Elasticities used in the model were taken from a variety of sources. Zone-specific output supply and input demand elasticities for Kenya were available from Munyi (2000). Labour supply elasticities were taken from Pitt and Sumodiningrat (1991). Consumption demand elasticities were adapted from Renkow's (1991) work in Pakistan. The 'borrowing' of elasticities estimates from locations outside of Kenya was lamentable, but unavoidable. Nonetheless, sensitivity analyses indicated that the simulations were generally not sensitive to our choice of elasticities (Karanja, 2002).

4. Results

Two sets of analyses were conducted to assess the long-run impacts of different regional patterns of technology adoption relative to a baseline case in which no technological change occurs. Fixed-price model simulations assumed that maize prices are determined exogenously (by government price policy or by the world market) with endogenous maize imports bridging the gap between domestic demand and supply. The flexible-price model simulations assumed that a national maize price is determined endogenously by domestic demand and supply conditions, but that the government has potential influence on prices via exogenous imports. Two simulations were conducted for each model, one in which technology adoption occurred only in marginal regions and one in which adoption was confined to high potential regions.

4.1. Fixed price simulations

Table 4 presents the simulated impacts on household farm profits and real income, based on the fixed-price model. Changes in the farm profits[4] of different household types depend on whether or not the household is a technology adopter, how labour-intensive maize farming is for the particular household, and whether the gains in productivity (positive effect) compensate

[4] The simulation results reported here assume no change in maize prices. Farm profits reflect both the returns to land and family labour.

Table 4
Fixed-price model simulation results (% changes)[a]

	Marginal regions				High potential regions		Urban areas	National[b]
	Lowlands	Dry mid-altitude	Moist mid-altitude	Dry transition	Moist transition	Highlands		
Technology adoption in marginal regions only								
Maize production	7.05	12.65	13.99	27.83	−0.54	−0.54	–	4.11
Imports	–	–	–	–	–	–	–	−15.32
Real agricultural wage	–	–	–	–	–	–	–	6.75
Farm profits[c]								
Small farms	−0.25	2.28	5.78	8.42	0.77	−0.81	–	1.49
Real income per capita								
Small farms	0.48	−0.61	2.25	3.29	0.23	−0.21	–	
Large farms	0.08	0.32	−1.21	0.96	−0.82	−0.79	–	0.30
Urban households	–	–	–	–	–	–	0.00	
Technology adoption in high potential regions only								
Maize production	−0.10	−0.10	−0.12	0.12	29.54	8.64	–	14.87
Imports	–	–	–	–	–	–	–	−49.12
Real agricultural wage	–	–	–	–	–	–	–	2.02
Farm profits[c]								
Small farms	−0.11	−0.17	−0.19	−0.18	11.49	2.57	–	2.89
Real income per capita								
Small farms	0.22	0.08	0.34	0.09	6.04	1.75	–	
Large farms	0.06	0.12	−0.66	0.15	11.16	1.45	–	1.84
Urban households	–	–	–	–	–	–	0.00	

[a] Assumes no change in maize prices, and thus no change in household-specific price indices. All values denote percentage changes relative to a baseline in which no technological change takes place and population and exogenous income growth follows recent patterns.
[b] National figures for maize production, farm profits and real income per capita are population-weighted averages of simulated regional changes.
[c] Profits include returns to land and returns to family on-farm labour.

for the higher labour costs induced by greater labour demand accompanying technology diffusion.

When technology diffusion occurs only in marginal regions, substantial upward pressure on real wages occurs. This is because technology packages for marginal zones tend to be relatively more labour-intensive. All households in marginal regions—except small farms in the Lowlands zone, whose share of maize profits in total farm profits is too low to compensate for increased labour costs—experience increased farm profits. On the other hand, farm profits generally fall for non-adopters in the high potential regions since their cost of production rises (due to higher wages) without a corresponding increase in maize productivity. The only exception is small farmers in the high potential Moist Transition zone who experience gains in farm profits aided by higher returns to family labour. The net impact of the maize technologies on real household incomes depend on changes in labour income and farm profits engendered by adoption of those technologies and the relative importance of those two components of total household income. Most households in marginal zones realise gains in real incomes, whereas (non-adopting) households in high potential regions experience a decline in real income. Because maize prices are exogenously determined in these scenarios, there is no change in household-specific price indices and, hence, there is no change in real incomes for urban households.

When technology diffusion is confined to high potential regions, wage effects are smaller and aggregate production is smaller vis-à-vis the scenario in which adoption occurs exclusively in marginal regions. All farms in the high potential regions enjoy higher profits, particularly those in the Moist Transition zone (where direct output effects are largest). Profits drop for all (non-adopting) farms in marginal regions, since the increase in labour costs is not compensated by any gains in productivity. With regard to real income effects, nearly all household types experience real income gains. Not surprisingly, increases in real incomes are larger for (adopting) households in the high potential regions—especially in the Moist Transition zone. Real income effects in the marginal regions are generally quite modest.

4.2. Flexible-price simulations

Table 5 presents the simulation results from the flexible-price model in which the price of maize varies with changes in aggregate maize supply while maize imports are exogenous (and assumed not to change from current levels). Price effects are particularly strong when technology adoption takes place in high potential zones, as supply shifts are greater in that scenario.

Because the maize price falls in these scenarios, simulated impacts on profits and total maize production are generally lower than in the fixed-price scenarios. Indeed, falling profits accompany technology adoption in the Highlands zone due to these negative price effects. When the technology diffusion occurs in the marginal regions only, profits generally increase (although not by as much as when prices were fixed).

The drop in maize prices causes household-specific price indices to fall, thereby increasing (reducing) the well-being of net consuming (net producing) households in proportion to household expenditure shares for maize. This, in conjunction with effects on farm

Table 5
Flexible-price model simulation results (% changes)[a]

	Marginal regions				High potential regions		Urban areas	National[b]
	Lowlands	Dry mid-altitude	Moist mid-altitude	Dry transition	Moist transition	Highlands		
Technology adoption in marginal regions only								
Maize production	6.23	10.98	12.72	26.42	−2.11	−1.89	–	2.66
Maize price	–	–	–	–	–	–	–	−3.61
Real agricultural wage	–	–	–	–	–	–	–	6.96
Farm profits[c]								
Small farms	−0.21	1.51	2.82	7.69	−1.25	−2.63	–	0.25
Real income per capita								
Small farms	1.72	−0.60	2.08	3.24	−0.42	−1.07	–	0.18
Large farms	1.32	−0.18	−2.87	3.28	−2.12	−1.41	–	0.18
Urban households	–	–	–	–	–	–	0.44	
Technology adoption in high potential regions only								
Maize production	−2.74	−5.46	−4.19	−4.63	24.51	4.32	–	10.22
Maize price	–	–	–	–	–	–	–	−11.59
Real agricultural wage	–	–	–	–	–	–	–	2.70
Farm profits[c]								
Small farms	0.40	−2.62	−7.65	−2.53	5.13	−2.91	–	−0.73
Real income per capita								
Small farms	4.2	0.13	−0.19	−0.05	3.99	−0.99	–	
Large farms	4.06	−1.50	−5.96	7.61	6.98	−0.52	–	
Urban households	–	–	–	–	–	–	1.43	

[a] Assumes no change in maize imports from baseline. All values denote percentage changes relative to a baseline in which no technological change takes place and population and exogenous income growth follows recent patterns.

[b] National figures for maize production, farm profits and real income per capita are population-weighted averages of simulated regional changes.

[c] Profits include returns to land and returns to family on-farm labour.

Table 6
Simulated aggregate real income increases and Gini coefficients[a]

	Fixed price scenarios			Flexible-price scenarios		
	Baseline	Adoption in marginal regions only	Adoption in high potential regions only	Baseline	Adoption in marginal regions only	Adoption in high potential regions only
Real income increase	–	0.30	1.84	–	0.18	1.31
Gini coefficient[b]	0.262	0.257	0.260	0.259	0.254	0.261

[a] Real income increases are computed as population-weighted averages of simulated household changes in real per capita income relative to simulated baseline income changes.

[b] Gini coefficients based on distribution of income implied by the changes in real incomes for different household types presented in Tables 4 and 5.

profits and household labour earnings, determines the overall changes in real household incomes.

When technology diffusion is confined to the marginal regions, five of eight household types in marginal zones enjoy net increases in real incomes, while all (non-adopting) households in high potential zones experience real income declines. But when the technology diffusion occurs exclusively in the high potential regions, households in the high potential Moist Transition zone enjoy real income increases, as do half of the household types in the marginal zones—mainly those that are net consumers and benefit from price declines.[5] But real incomes still decline for farms in the high potential Highlands zone, since these are net producing households for whom farm profits fall. Finally, urban households benefit from falling maize prices in all flexible-price scenarios, particularly those in which technology adoption is assumed to take place in the high potential zones.

4.3. Income distribution effects

Table 6 indicates the changes in aggregate real income and income distribution implied by the simulation results of Tables 4 and 5. For each scenario considered, aggregate real income increases were computed as population-weighted averages of household changes in real per capita income relative to a simulated baseline income changes. Gini coefficients were then computed based on the distribution of income implied by changes in real incomes for different household types. For comparative purposes, a Gini coefficient was also computed for the income distribution implied by the baselines for both fixed- and flexible-price scenarios.

Adoption of maize technologies that have been developed for high potential regions produces strikingly larger positive impacts on aggregate real incomes than adoption of technologies available to farmers in marginal agro-ecological zones. Indeed, the simulation results suggest that the overall impact on aggregate income of marginal region technologies are extremely modest, although some household types in marginal zones do enjoy significant income increases.

In the aggregate, real income effects are somewhat lower in the flexible-price scenarios than in the fixed-price scenarios. This is interesting insofar as one regards the fixed- and flexible-price models as representative of pre- and post-liberalisation structure of Kenya's maize markets—the implication being that liberalisation has attenuated the potential positive welfare impacts technological change. It is important to recognise, however, that our simulations in no way account for some of the welfare-reducing deadweight losses associated with the institutional structures that were dismantled as a part of the liberalisation process.

On the other hand, the computed Gini coefficients indicate that adoption of maize technologies that have been developed for high potential regions produce a somewhat less equal income distribution than adoption of technologies available to farmers in marginal regions. Moreover, under both fixed- and flexible-price models, technology adoption in marginal areas leads

[5] Note that the marginal zone households for which real income increases are relatively large—large farms in the Dry Transition zone and both small and large farms in the Lowlands zone have the largest maize expenditure shares of all household types considered.

to more equal distributional outcomes than in the baseline. Indeed, under the assumption that the maize prices is endogenously determined, the simulations suggest that technology adoption in high potential regions actually leads to a more unequal income distribution than if there were no adoption (i.e., the baseline case).

5. Concluding remarks

Our results suggest several general conclusions. First, maize technologies that have been developed for high potential regions are likely to have more profound aggregate impacts on maize production than technologies that have been developed for marginal regions. Thus, technology adoption in high potential regions will lead to correspondingly greater reductions in import demand (if maize prices are controlled) or maize prices (if maize prices are flexible).

Second, diffusion of technologies in high potential areas is likely to have substantially greater positive impacts on aggregate farm profits and real incomes. Indeed, the simulation results suggest that the overall impact on aggregate income of marginal region technologies are extremely modest, although some household types in marginal zones do enjoy significant income increases.

Third, the way in which the maize market clears has important ramifications for both the magnitude and distribution of gains and losses from various scenarios of technology adoption: when maize prices are exogenously determined, aggregate income increases are generally somewhat greater, and the number of household types that suffer real income losses is smaller, compared to when prices are endogenously determined. A notable exception to this latter point is urban households, for whom welfare increases when prices are endogenous and remains the same when prices are exogenous.

Finally, although diffusion of technologies in high potential regions has substantially greater impact on aggregate real incomes, it produces more unequal income distribution outcomes compared to diffusion of technologies in marginal regions. This suggests a classic dilemma between income maximisation and distributional goals, the resolution of which requires grappling with the relative social importance of these two important policy objectives. These findings underscore the difficulties confronting Kenyan policymakers and research managers in choosing between competing research resource allocation options.

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