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Off-farm Employment and Input Intensification among Smallholder Maize Farmers in Kenya

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Abstract

We derive input demand functions for fertiliser and hybrid seed, testing for the combined and separate effects of income from non-farm sources and agricultural wage labour among smallholder maize farmers in Kenya. More income from off-farm sources, and specifically non-farm sources, competes with maize intensification, particularly in more productive areas where use rates are higher. In less productive areas, where households rely more on off-farm income and input use in maize is extremely low, agricultural wage labour reduces the likelihood that fertiliser is applied, but when used, has a positive effect on quantities purchased of both seed and fertiliser.

Keywords: *fertiliser*; *hybrid maize*; *input intensification*; *Kenya*; *off-farm work*.

JEL classifications: *J430, O12, Q12.*

1. Introduction

During early stages of economic development in predominantly rural societies, it has long been argued that growth in agricultural productivity is necessary to raise farm incomes and to stimulate the development of the rural non-farm economy (Timmer, 1984; Block, 1994). According to this viewpoint, unless productivity growth occurs in agriculture, broader growth in the rural economy will be constrained and poverty reduction much more difficult to achieve. Grounded largely on the historical experiences of the Green Revolution in South Asia (Djurfeldt, 2012), this perspective is supported by a body of recent research conducted in Sub-Saharan Africa (e.g. Diao *et al.*, 2010). The 2008 World Development Report (2007) redirected policy

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attention to the role of smallholder farmers as agents of poverty-reducing, agricultural growth.

Three observations are noteworthy in this regard. First, sustained productivity growth in the smallholder sector, particularly in staple food crops, has been especially difficult to achieve in Sub-Saharan Africa (SSA). Second, research has demonstrated that although situations vary widely, rural non-farm earnings account for an average of one third of total income (Reardon *et al.*, 2007). Third, agricultural credit for smallholder farmers continues to be severely lacking in most countries of SSA. This is especially true for food crops such as maize, grown by widely dispersed smallholders with differentiated capital endowments under heterogeneous growing conditions. Particularly since liberalisation of staple food markets with structural adjustment programmes launched during the 1990s, food crops lack the institutional arrangements that relieve credit constraints for cash crops such as coffee, tea and cotton, which are organised as well-integrated value chains. Under such circumstances, agricultural intensification may be reliant on cash generated within the household.

These points underscore the potentially important role that off-farm employment can play in agricultural intensification, although a considerable literature on the topic provides mixed evidence (Reardon, 1997; Barrett *et al.*, 2001, 2005; Lanjouw, 2007; Haggblade *et al.*, 2010). While a number of studies have made empirical contributions to understanding the role of off-farm employment and farm production, less is known about the exact nature of the interaction between these two sectors at the scale of the individual household. Until recently, few studies have formally tested the relationship between non-farm employment and smallholder investment in agriculture, such as the choice of farming technology (Davis *et al.*, 2009). Several early empirical studies found positive evidence for the direction of off-farm work effects on various forms of farm investment. For example, Savadogo *et al.* (1994) concluded that non-farm earnings positively influence the adoption of animal traction. Clay *et al.* (1998) found a positive effect of non-cropping income on land conservation investments but an insignificant effect on use of chemical inputs. Over the past decade, analysts have begun to examine these relationships with greater analytical rigour. Some studies have explored the effects of off-farm work on farm investment (Ahituv and Kimhi, 2002; Chikwama, 2004; Morera and Gladwin, 2006). Though using different approaches and analytical tools, most of these studies identify a negative relationship between off-farm work and investment in agricultural production.

In this paper we test whether income from off-farm work contributes to productivity-enhancing investments by smallholder farmers in Kenya. We specifically test the effects of off-farm earnings, combined and differentiated by source, on use of fertiliser and hybrid seed among these smallholder farmers. Consistent with Lamb (2003), we argue *a priori* that earnings from off the farm may be used to compensate for missing and imperfect credit markets by providing ready cash for input purchases as well as other household needs. This view is also supported by previous research (Collier and Lal, 1984; Reardon et al., 1994; and Barrett *et al.*, 2001).

On the other hand, we recognise that engagement of household members in non-farm activities can divert labour resources from agricultural activities and peak period tasks. We expect that income from non-agricultural sources, such as migrant remittances, earnings from salaried employment outside the community, or from non-farm businesses will not have the same effect as payment for piece work on neighbouring farms during peak periods in the cropping cycle. Smallholder farmers selling wage labour to other households generally do so because they have an immediate need to generate cash. Working for other farms nearby may also be a way to obtain agricultural inputs that otherwise would not be affordable. The timing of this piece work may however conflict with time allocation to crop-related tasks on the family farm.

We choose maize to explore this relationship for the following reasons. First, it is the most widely grown and locally traded crop in Kenya. Maize is by far the main staple food in the country and accounts for about 28% of gross farm output from the small-scale farming sector. Outside the semi-arid areas, 98% of households grow maize. Second, our data show that roughly two thirds of smallholders surveyed in these areas grew hybrid seed and used fertiliser. Finally, there is no organised credit system for maize, generating the need for other off-farm sources of cash to finance input purchases.

In section 2, we develop a conceptual model to frame and motivate the empirical approach. Section 3 describes the data, empirical model estimation issues. We present results in section 4, and draw conclusions in the final section.

2. Theoretical Approach

We consider a household engaged in a portfolio of on-farm and off-farm activities under risky conditions. To simplify the derivations, we focus on two rather than n periods, although this should not affect the key implications from the model. Returns from each activity are uncertain and imperfectly correlated. In a two-period decision model, the household decides how to allocate its time and previously earned income in period $t = 0$, which precedes planting. Earned cash can be spent on input purchases, on hired farm labour, or can be invested in an off-farm enterprise, among others. The household may also attempt in this initial period to obtain credit. In the second period ($t = 1$), during the cropping season and after harvest, the household earns income and repays credit.

We define an on-farm production function $Q = Q(L_f, L_h, \mathbf{Z}: A, H, G)$, where L_f is on-farm family labour, L_h is hired labour, $\mathbf{Z}$ represents a vector of purchased inputs, and A, H and G represent agro-ecological conditions, household characteristics (specifically, human capital), and other locational characteristics (such as distances to input markets), respectively. H embodies both the skills and the orientation of the household. The household is endowed with a quantity of labour time, $L = L_o + L_f$, where L_o represents off-farm labour. Purchased inputs and on-farm labour (both family and hired) are assumed to be complements in production.

The household's objective is to maximise the risk-adjusted discounted total net earnings (Y) from its portfolio; only revenues and costs from the second period are discounted:

$$Y = \left[\frac{R_1}{1+r+\alpha} - C_0\right] + \left[CR_0 - \frac{CR_1'}{1+r+\alpha}\right]. \tag{1}$$

where all subscripts indicate time period, R_1 is total revenue (on- and off-farm), C_0 is total costs (on- and off-farm), r is the household's risk-free discount rate, α is its risk premium, and CR_1' is the nominal value of repaid credit. In a credit-constrained world, credit (CR_0), cash allocated to activities (C_O), and the quantity of purchased inputs and hired labour are determined simultaneously.

Incorporating the production function and time constraint, we have:

$$\text{Max}(Y) = \left[\frac{P_1^Q Q(\cdot) + W_1^o L_1^o(\cdot)}{(1+r+\alpha)} - P_0^z Z_0 - W_0^h L_0^h(\cdot) - C_0^o(\cdot)\right] + \left[CR_0(\cdot) - \frac{CR_0(\cdot)(1+r')}{(1+r+\alpha)}\right]. \quad (2)$$

where P_1^Q is output price, W_1^O is the off-farm wage rate, P_0^Z is the price of inputs, W_0^h is the wage paid to hired labour, $C_0^O(\cdot)$ is cash allocated to off-farm work at period $t = 0$, and r' is the rate of interest paid on any credit the household obtains. The first term in brackets is the risk-adjusted discounted net earnings on- and off-farm, while the second bracketed term is the risk-adjusted discounted cost of credit.

Taking first-order conditions with respect to **Z**, we obtain:

$$Z: \frac{P^Q\left(\frac{\partial Q}{\partial Z} + \frac{\partial Q}{\partial L^f}\frac{\partial L^f}{\partial Z} + \frac{\partial Q}{\partial L^h}\frac{\partial L^h}{\partial Z}\right) + W^o\frac{\partial L^o}{\partial Z}}{(1+r+\alpha)} - P^z - W^h\frac{\partial L^h}{\partial Z} - \frac{\partial C^o}{\partial Z} + \frac{\partial CR}{\partial Z}\left(1 - \frac{1+r'}{1+r+\alpha}\right) - \lambda\left(\frac{\partial L^o}{\partial Z} + \frac{\partial L^f}{\partial Z}\right) = 0. \quad (3)$$

where λ is the shadow wage rate. Re-arranging, we find the optimality conditions:

$$P^Z = \frac{P^Q\frac{\partial Q}{\partial Z}}{1+r+\alpha} + \left(\frac{P^Q\frac{\partial Q}{\partial L^f}}{1+r+\alpha} - \lambda\right)\frac{\partial L^f}{\partial Z} + \left(\frac{P^Q\frac{\partial Q}{\partial L^h}}{1+r+\alpha} - W^h\right)\frac{\partial L^h}{\partial Z} + \left(\frac{W^O}{1+r\alpha} - \lambda\right)\frac{\partial L^O}{\partial Z} + \frac{\partial CR}{\partial Z}\left(1 - \frac{1+r'}{1+r+\alpha}\right) - \frac{\partial C^o}{\partial Z}. \quad (4)$$

Equation (4) indicates that at the optimal solution, inputs should be used to the indicate where the risk-adjusted discounted marginal value product (MVP) of inputs equals its price. The first term on the right is the risk-adjusted discounted MVP of inputs without taking into account imperfections in labour and credit markets, which can be denoted as MVP'_Z. We find that accounting for the risk associated with earnings reduces MVP'_Z , thus resulting in decreased input use. More specifically, MVP'_Z is decreasing in the variance of returns to input use and in the correlation of those returns with returns from the existing portfolio. Using the familiar Beta approach (Boardman *et al.*, 2001, p. 251), we can represent the risk premium as:

$$\alpha = \lfloor E(r_m) - r_f \rfloor \beta_j \quad (5)$$

where

$$\beta_j = \frac{\text{Cov}(r_m r_j)}{\text{Var}_m} = \sigma_{jm}\frac{\sigma_j}{\sigma_m} \quad (6)$$

where r denotes a rate of return, subscripts m, j, and f refer respectively to the portfolio, the investment/activity of interest, and a risk-free asset, E is the expectations operator, ρ denotes a correlation coefficient, and σ denotes standard deviation. β_{j} (and hence α) increases – and MVP'_Z declines – with the variance of returns of the investment of interest (as indicated by σj) and with its correlation with the existing portfolio (ρjm).

Terms two to four in equation (4) capture the effects of labour market imperfections. Examining the second term, the bracket is the risk-adjusted discounted MVP of family labour on the farm minus the shadow wage rate. This value is multiplied by the marginal effect of inputs on family labour use on the farm (assumed positive, as the two are complements). Assuming household input choices do not affect input prices, the bracketed term is non-negative, and will equal zero if the household is able to optimise its time allocation. If non-zero, this term decreases in risk. The same logic applies to the third term: an optimising household will not pay hired labour more than its risk-adjusted discounted marginal value product, and the term is thus either equal to zero or, if non-zero, is decreasing in risk.

By the same logic, the fourth term will be either zero or negative, since $\partial L^O/\partial Z$ is expected to be negative. However, because few households hire in farm labour, $\partial L^O/\partial Z$ for most households will (by the labour constraint) be comparable in absolute value to $\partial L^f/\partial Z$. As a group, therefore, we expect terms two to four to be positive or zero and, if positive, to be decreasing in risk. These terms thus reinforce the effect of risk seen in the first term, implying that demand for inputs will decrease with the variance of returns to their use and with their covariance with the existing portfolio.

The fifth and sixth terms capture imperfections in credit markets. The partial derivative in the fifth term is positive, and the bracketed term is positive or zero: a household will not pay more than $r + \alpha$ in interest, and perfectly competitive credit markets dictate $r' = (r + \alpha)$. Demand for inputs will rise for households able to obtain credit at rates below $(r + \alpha)$. An example here would be households that belong to farmer groups/cooperatives which generally provide inputs at lower cost through bulk buying and lower borrowing rates. Finally, perfectly competitive credit markets will allow decisions on purchase of inputs and investment in an off-farm enterprise to be made independently, driving both these terms to zero. However, in the case of maize production in Kenya, where no organised system for credit is available for purchasing fertiliser or hybrid seed, the fifth and sixth terms are also zero. Informal credit sources might be used, however, to offset other cash constraints on the household farm, affecting maize production indirectly.

Thus, including off-farm considerations in modeling maize intensification in Kenya, as captured in term four and in the absence of credit provision, is predicted to have a negative effect on input use. When informal credit sources are utilised by the farm household, the predicted effect is ambiguous. This is consistent with Wozniak's argument (1993), and our own hypothesis, that the positive effect of off-farm wage income on the likelihood of farm technology adoption may be offset by the reduction in time available for producing knowledge and making farm decisions, as well as the increased opportunity cost of time. A similar approach has been applied to model time to adoption, while considering the influence of off-farm income, by Abdulai and Huffman (2005) for the time to adoption of cross-bred cows and Dong and Saha (1998) for adoption of high-yield varieties in Tanzania.

Other hypotheses can be derived from equation (4). In general, anything that increases (decreases) the right-hand side of equation (4) will increase (decrease) demand for inputs. Thus, in addition to the above, we can also generate the following expectations regarding MVP'_Z. First, it is increasing in A by the definition of A. That is, the more favourable the agro-ecological conditions for maize production, the greater the input use. Second, MVP'_Z is ambiguous in education (a key component of H): while education should increase skills that would increase the efficiency of input use, it may also reflect greater opportunities for off-farm activities, which would tend to decrease input use efficiency.

To evaluate the implications of this theoretical model on farm input use, we solve the resulting first-order conditions with respect to all the choice variables to derive input and labour demand functions. In particular, the input demand function defined by the vector of inputs **Z** is given by:

$$\mathbf{Z}^* = f(w^h, W^O, P^Z, P^Q, A, H, G) \tag{7}$$

CR is endogenous in this model, and is not included in the reduced form. According to modern portfolio theory (MPT), diversification involves the reduction of market risk through investment in several instruments with imperfectly correlated returns. Thus, in making decisions on whether to invest earnings from off-farm into farming activities, our conceptual model shows that farm households consider how the anticipated returns may be correlated with their current portfolio. Since diversification does not eliminate all variance (Markowitz, 1952), the optimal portfolio is a trade-off between expected returns and associated risk. On the margin, a household's propensity to invest off-farm earnings into farm intensification will depend on (i) the expected returns from intensification (and their variance) as dictated by agro-climatic conditions and the household's aptitude for farming, and (ii) the correlation of those returns with the existing portfolio. Of particular interest here is the type of off-farm activity already in the portfolio, and its relationship to farm activities.

The fact that off-farm activities may differ in their relative returns and riskiness, and more importantly in how they relate to farm activities, is an indication that the probability that earnings from these activities will be invested in agriculture may also differ by type of off-farm activity. In this study, we explore the impacts of two different types of off-farm earning activities, based on their stability and likely correlation between their returns and returns to agriculture: non-farm earnings (salaried labour/pension, remittances, and other business and service activities), and agricultural labour on other farms (farm *kibarua*). Generally speaking, we expect that overall returns from non-farm earnings are likely to have low correlation with earnings from agriculture, particularly for salaries and wages as compared to either remittances or earnings from informal, localised business and services. Remittances are likely to be a heterogeneous category, because the level, timing and volatility of income from this source for the receiving households depends on the characteristics of the remitter, including their relationship with the household, and on the characteristics and geographical location of activities they engage in. We can, however, draw *a priori* expectations from Collier and Lal (1984) who found that in Kenya, remittance income from urban wage employment was being used to finance farming activities, resulting in increased agricultural incomes. Other business and service activities are also more likely to depend on local demand, meaning that returns are expected to be correlated with returns to the dominant income source in the area. By contrast, earnings from piece work on other farms are expected to be highly correlated with farm earnings, and unstable. In addition, these may be sought and received during peak labour periods for maize production, when fertiliser is applied and plants are weeded, detracting from labour inputs that are complementary to intensification.

3. Data and Methods

3.1. Data

The sampling frame for the panel survey was prepared in 1997 in consultation with the Central Bureau of Statistics (CBS), currently the Kenya National Bureau of Statistics (KNBS). The process is described by Argwings-Kodhek G., (1999). Census data were used to identify all non-urban divisions in the country, and these were assigned to one or more agro-ecological zones (AEZ) based on the 1990 Census, District Development Plans and the Farm Management Handbook. Within each AEZ, two or three divisions were chosen based on their importance (size of population). In each selected division, villages were randomly selected. Households were selected within selected villages with systematic sampling, and a random start. A total of 1,578 households were selected in 24 districts. For the purposes of analysis, the selected households were then grouped into nine agro-regional zones, which represented a combination of AEZ and administrative boundaries.

The data for 1997 are excluded in this analysis owing to lack of comparability in some of the key variables of interest, but the sampling frame is the same in 1997, 2000 and 2004. The balanced sample used in this study consists of 1,243 maize-producing rural households in 2000 and 2004, including farming areas with higher productivity potential such as the Central and Western Highlands of Kenya, low potential areas such as the coastal, eastern and western lowlands, and other medium potential areas. The data record information on economic, demographic and other locational characteristics of the households.

3.2. Econometric model and variables

We estimated input demand functions following equation (7), indexed by household (i) and time period (t). Separate regression models for fertiliser and hybrid seed were estimated, each with aggregated off-farm income and income disaggregated by non-farm and farm *kibarua* sources. In addition, we estimate each set of models by agricultural potential to assess differences by production environment.

Table 1 presents the description of variables used in this study including their means and standard deviations. The dependent variables (**Z**) include the binary input adoption variables and the intensity of use as given by the amount of fertiliser and hybrid seed used by the households.

Input prices (fertiliser, seed, farm wage rate) and the maize grain price were included to control for variations in input use as a result of changes in economic incentives facing households (w, **P**). Each input price series was computed as the village-average farmgate price reported by farmers in the relevant year. In the case of the fertiliser price, farmgate prices were weighted by the share of the total kgs purchased of each type. Grain prices and farm wages are village averages.

We examined the survey data regarding credit use. In 2004, only 80 of a total of 613 households who received credit received it in cash. As reported by respondents, only 33 of these were for fertiliser and 9 for seed, but not for maize. Credit was generally received via group membership in cooperatives producing sugar, tea, wheat, dairy or coffee, and most often in kind. In 2000, the corresponding numbers were 74 out of 995, with 23 for fertiliser and 11 for seed. The correlation matrix of off-farm earnings and credit receipts shows no significant association between any off-farm source (all $P > 0.28$).

Table 1
Summary statistics for variables in regressions

Variable	Definition	Mean	Std deviation
Dependent variables			
Fertiliser use	1 = apply fertiliser to maize, 0 otherwise	0.67	0.47
Seed use	1 = plant hybrid seed; 0 otherwise	0.65	0.48
Fertiliser amount used	kgs applied to maize	68.7	220.1
Seed amount used	kgs hybrid maize seed planted	12.3	29.6
Prices			
Fertiliser price	Village-average, kg-weighted farmgate cost of fertiliser applied to maize	27.8	3.34
Seed price	Village-average, kg-weighted farmgate cost of seed planted	134	9.23
Grain price	Village-average farmgate price of maize	13.3	2.18
Farm wage rate	Village-average wage paid to farm labour	78.0	33.1
Locational characteristics			
Distance to fertiliser	kms to nearest fertiliser source	4.94	7.88
Distance to seed	kms to nearest seller of certified seed	4.72	7.47
Household characteristics			
Farm size	ha owned by household	6.09	8.73
Education	average education of adults in household	7.17	2.93
Young adults	Number of adults 15–24 years	2.01	1.63
Mature adults	Number of adults 25–64 years	2.30	1.28
Agro-ecology			
Rainfall	Total mm rain in the main growing season associated with the survey year	543	171
Soil quality	1 = village has soils with high humus content according to FAO classification (see text); 0 otherwise	0.19	0.39
Crop diversification	Simpson crop diversity index (1 − sum of squared area shares planted to each crop)	0.63	0.20
Income			
Off-farm income	Combined income from non-farm sources and other farm labour, in nominal KES	65,396	124,252
Non-farm income	Income from salaries, wages and remittances, in nominal KES	63,649	124,371
Farm labour	Income from farm labour on other farms (*kibarua*), in nominal KES	1,747	8,315
Instrumental variables			
Telephone	Median kms from of all village households to public telephone (fixed)	3.96	3.53
Electricity	Median kms from of all village households to public telephone	4.33	6.76

Source: Authors.

On this basis, *CR* is represented by off-farm earnings (including two categories of non-farm and farm labour). We used Simpson's index of crop diversification, a metric constructed over income shares and the number of crops grown in both seasons, as an indicator of the scope of agricultural activities in which the household engages. This variable captures the multiproduct nature of farms, and helps to control for the possible diversion of fertiliser from other crops to maize, and vice versa.

A represents agro-ecological features of the farm (agricultural zone, rainfall and soil quality). The data used in this study span areas of differing agricultural potential and planting seasons. The high potential maize-growing area in the more productive environment has one rainy season while other areas have a bimodal rainfall pattern. In 2010, according to Tegemeo data, the higher potential agricultural areas produced about half (47.6%) of Kenya's maize and supplied nearly three quarters (72.1%) of the maize that was marketed in the country. About one third (36%) of all maize produced in other areas was sold in that year, as compared to 55% in the zones with higher productivity potential.

The inclusion of the long-term (village) rainfall variable helps to control for heterogeneity across zones and regions. Recognising the significance of soil quality, we have also included a village-specific dummy variable for high humus content or highly productive soils, based on detailed work by Sheahan (2011) with FAO soil classes. FAO classifies soils based on their formation process and overarching properties. High humus soils have nutrient–rich material resulting from the decomposition of organic matter and are found in areas which were originally under forest or grassland. Unfortunately, household-specific soils data of this type are not available at a national scale.

We controlled for household resource endowments and characteristics (H) using the average education of adults in the household and farm size. Consistent with other studies (Lamb, 2003), our conceptual model assumes that input use and farm labour are complements in production. Thus, we included number of adult household members to control for labour availability.

We cannot form clear *a priori* expectations concerning the directional effect of most of our variables. First, while education may imply more specialisation in off-farm work, the ability to obtain earnings from these activities may also allow households to take on more risk from agricultural production. However, based on extensive literature showing higher returns to education in the off-farm sector (e.g. Huffman, 1980; Yang, 1997), it is plausible to expect that, holding all other factors constant, more educated households may prefer to invest their off-farm earnings outside their farms. Second, although households in high potential maize-growing areas may generally invest more in input use (given the higher expected returns), it may be difficult to isolate the specific off-farm work effects from these general effects. Application of fertiliser to degraded soils is unlikely to be profitable (Marenya and Barrett, 2009). Thus, at low overall rates of fertiliser application, such as those found across Sub-Saharan Africa (Morris *et al.*, 2007), we may find that farmers in regions with better soils actually apply more fertiliser than those in less favourable areas. Further, we expect households with a broader range of crop income sources and larger farm size to be able to more easily finance farm intensification, either directly or through access to credit.

3.3. Estimation issues

Two specification issues, in particular, are encountered in estimating this model. The first is non-use of inputs. As indicated in Table 1, about 67% and 65% of households used fertiliser and hybrid seed, respectively, clearly indicating that some households did not use these inputs. The Tobit model is widely used to estimate censored variables of this type, but suffers from the limitation that it treats the decision to use an input and the amount used as generated by the same underlying processes. This implies that the same set of parameters and variables determine both the discrete probability of adoption and the intensity of use. The double hurdle model relaxes the above assumption, and is used here. The specification enables the modeling of two separate decisions: the decision to use an input and the intensity of use. In this study, we use the truncated normal distribution version of the double hurdle model. The advantage of this model (Cragg, 1971) is that it nests the usual Tobit, thus allowing us to test whether the restrictions of the Tobit model are binding or not. The highly skewed distributions of the intensity variables led us to use the natural logarithms in the second tier.

Second, there is a potential problem of simultaneity between off-farm work and farm production and investment decisions: while input use could depend on earnings from off-farm work, involvement in off-farm work could be triggered by financial need for farm inputs or unemployment of family labour. In addition, involvement in off-farm work could compete for labour and capital with farming activities especially where input markets are missing. To test and control for potential endogeneity in such a non-linear model (Wooldridge, 2010), we apply the control function approach (CFA).

As in a two-stage least squares (2SLS) model, the CFA requires use of instrumental variables to test for endogeneity. Our instrumental variables are the median kilometres from the households in the sample village to the nearest public telephone and source of electricity. Access to mobile phones was not widespread until recently, and nor was it recorded across all years in the data. The logic behind the use of these two variables is that (i) they are not choice variables, and (ii) they are correlated with the presence of the infrastructure that affects non-farm employment opportunities, but not necessarily input use. The first stage involves regressing the suspected endogenous variable on the instruments and all the explanatory variables in the structural model. In the second stage, however, the structural model is estimated with the observed endogenous variable and the residual from the first stage added as explanatory variables. The test of endogeneity is the statistical significance of the coefficient of the residual, when the regression is estimated with bootstrapped standard errors. The control function approach is described in early work by Smith and Blundell (1986).

Given the difficulties in controlling for unobserved heterogeneity in non-linear models, we use the correlated random effects (CRE) model. As proposed by Mundlak (1978) and Chamberlain (1984), the CRE model helps to control for unobserved heterogeneity and its correlation with observed factors in non-linear models. Application of the model requires that the means of time-varying explanatory variables are included as additional regressors in the model.

Although theory does not clearly point to the necessity of imposing exclusion restrictions in the double hurdle model (as with the Heckman model), we exclude distance to the respective input supplier in the second stage of the estimation. This is plausible given that distance traveled may be largely a fixed cost for the second hurdle, and is thus unlikely to affect the quantity decision, consistent with Ariga *et al.* (2006).

Table 2

Off-farm earnings and earnings share of total household income, by maize production environment and year

Production area		2000 Off-farm income	2000 Non-farm income	2000 Farm *kibarua* income	2004 Off-farm income	2004 Non-farm income	2004 Farm *kibarua* income
Earnings (KES nominal)							
Low agricultural potential	Mean	55,804	53,475	2,329	91,688	89,803	1,886
	St dev	78,561	78,750	9,115	133,472	133,176	10,715
High agricultural potential	Mean	56,657	54,791	1,866	66,269*	64,981*	1,288
	St dev	98,370	98,487	7,353	155,080	155,345	7,486
Total	Mean	56,384	54,370	2,014	74,408	72,929	1,480
	St dev	92,459	92,596	7,959	148,924	149,005	8,652
Income share							
Low agricultural potential	Mean	0.443	0.412	0.0311	0.508	0.491	0.0166
	St dev	0.294	0.296	0.109	0.306	0.309	0.0863
High agricultural potential	Mean	0.269*	0.245*	0.024	0.265*	0.248*	0.0175
	St dev	0.257	0.252	0.0906	0.261	0.257	0.0836
Total	Mean	0.325	0.298	0.0262	0.343	0.325	0.0172
	St dev	0.281	0.278	0.0969	0.298	0.297	0.0844

Note: *Differences are statistically significant between zones.
Source: Authors.

4. Results

Descriptive statistics for major variables of interest are shown by production environment in Table 2 and in the online Appendix found in the Additional Supporting Information. Income (KES) earned from off-farm employment differs significantly between production environments only in 2004, when amounts of off-farm and non-farm income are higher in the areas with lower agricultural potential (Table 2). Although cash earned from agricultural wage labour also appears to be greater on average in this zone, the difference is not statistically significant due to the variance of the variable. More importantly for this analysis, Table 2 shows the markedly greater dependence of the maize-growing households in lower potential areas on off-farm income, in both seasons. In either zone, households earn very little of their income from *kibarua* sources.

Use of both fertiliser and hybrid seed in maize production is in the order of several times greater in the higher potential agricultural areas. The amount of hybrid seed used, on average, corresponds to a minor fraction of a hectare in the lower potential areas in both survey years, and the amounts of fertiliser applied are similarly very small. All indicators of maize intensification differ significantly between production environments in both years (see the online Appendix). Income from maize production is of course substantially higher in the higher potential zone.

Turning to the regressions, we estimated fertiliser and hybrid seed demand functions using the Correlated Random Effects model. We use the control function approach to test and deal with the endogeneity of the off-farm work variable. Separate models with the aggregated and disaggregated off-farm work variable are

Table 3

CRE double hurdle models estimating demand for fertiliser and hybrid seed in maize production, including non-farm income and labour on other farms, higher potential agricultural areas

	Fertiliser use		Hybrid seed	
	Binary	Ln (kgs)	Binary	Ln (kgs)
Fertiliser price	7.08	−0.11***	−0.13***	−0.027*
	(624.3)	(0.018)	(0.023)	(0.014)
Seed price	−2.55	−0.04***	−0.032***	−0.054***
	(208.4)	(0.0075)	(0.01)	(0.006)
Grain price	−2.02	0.044**	0.080***	0.024
	(651.2)	(0.02)	(0.026)	(0.016)
Wage rate	−0.10	−0.0027*	0.0017	−0.003***
	(46.6)	(0.0015)	(0.002)	(0.0011)
Distance to fertiliser	2.174			
	(694.0)			
Distance to seed			−0.0044	
			(0.019)	
Farm size	4.89	0.049***	0.015	0.009
	(350.0)	(0.015)	(0.025)	(0.009)
Education	−0.37	0.0103***	0.0032	0.0075***
	(135.9)	(0.0029)	(0.0038)	(0.0024)
Young adults	−9.141	0.221***	0.0212	0.172***
	(1,398)	(0.063)	(0.088)	(0.049)
Mature adults	−24.36	0.524***	0.033	0.422***
	(3,597)	(0.172)	(0.233)	(0.134)
2004	−39.61	0.666***	0.545**	0.243**
	(7,915)	(0.193)	(0.242)	(0.114)
Rainfall	−0.0032	−0.0012	0.0018	−0.0016**
	(16.71)	(0.0009)	(0.0012)	(0.0007)
Good soils	−8.840	0.356***	−0.069	0.233***
	(4,379)	(0.07)	(0.096)	(0.052)
Crop diversification	79.48	−0.105	0.535	−0.181
	(8,712)	(0.28)	(0.363)	(0.208)
Non-farm income	0.000703	−2.19e-05***	−1.46e-06	−1.71e-05***
	(0.148)	(6.61e-06)	(9.01e-06)	(5.23e-06)
Residual1	−0.00073	2.22e-05***	2.59e-06	1.72e-05***
	(0.149)	(6.61e-06)	(9.00e-06)	(5.24e-06)
Farm labour	0.0011	−7.07e-06	2.71e-05	−5.27e-06
	(0.449)	(1.95e-05)	(2.20e-05)	(9.87e-06)
Residual2	−0.0012	−2.41e-06	−3.79e-05*	4.22e-06
	(0.351)	(1.91e-05)	(2.16e-05)	(9.34e-06)
Constant	316.5	10.94***	6.98***	10.10***
	(32,828)	(1.318)	(1.754)	(1.004)
Observations	1647	1647	1647	1647
Wald chi (23)	142.11		97.55	
Log likelihood	−2,626.50		−2,245.33	

Notes: Robust standard errors given in parentheses. ***P < 0.01, **P < 0.05, *P < 0.1.
Source: Authors.

estimated and reported. Aggregated results can be found in the online Appendix; the latter separate non-farm income from farm labour and are reported here. Separate models for high and low agricultural potential areas are also reported in addition to the general model.

Results for the models that test the significance of non-farm earnings and *kibarua* income on use of hybrid seed and fertiliser in maize production are shown for the higher potential zone in Table 3. Here, non-farm income has a negative influence on demand for both fertiliser and hybrid seed in maize production, and appears to be endogenous in intensification decisions. On the other hand, the coefficients related to farm labour are not statistically significant. Certainly, as noted in Table 2, the amounts and shares of household income earned from farm *kibarua* are limited and variable relative to non-farm sources, which make up the majority of off-farm earnings, on average.

Consistent with economic theory, both fertiliser and hybrid seed prices dampen demand for fertiliser and hybrid seed, but grain price has a positive effect on either fertiliser or hybrid seed demand. These findings are suggestive of a commercial production response. Binding labour constraints are demonstrated in the positive signs and significance of the numbers of young and mature adults among household members. The wage rate decreases use of fertiliser and hybrid seed, which require additional labour. The negative sign on the wage rate is predicted by economic theory, and reinforces the results on household labour concerning overall labour constraints in the areas with higher agricultural productivity.

Distance to the nearest input seller has no significant effect on the probability of using either of the inputs. It is noteworthy, however, that the average distance to the nearest fertiliser seller has declined from 4.7 km in 2000 to 3.2 km in 2004 and from 4.5 to 2.9 km for hybrid seed which could be a result of improved input delivery systems after liberalisation, a point well advanced by Freeman and Omiti (2003) and Ariga *et al*. (2006).

Most of the other control variables behaved as expected. Larger farm sizes are found to exert a positive scale effect on the demand for fertiliser. Education has a strong and positive influence on maize intensification, which is broadly consistent with the agricultural development literature and with other research in Kenya. Both more fertiliser is applied and more hybrid seed is planted in villages with better soils. This finding is consistent with the fact that hybrid seed has a steep yield response to fertiliser, and that soils with more organic matter and humus may also better integrate mineral fertilisers. Crop diversification, our indicator of the portfolio of cropping activities and crop income sources aside from off-farm sources, does not appear to be important.

It is noteworthy that the effects of earnings from farm *kibarua* are evident in both the fertiliser and seed regressions for low agricultural potential areas (Table 4). That is, more income from labour on other farms reduces the probability that fertiliser is used on maize, by a large amount, although it also increases the kgs applied if fertiliser is used. At the same time, farm households that earn more on other farms grow more hybrid seed, on average, than others. Whereas fertiliser is applied throughout the growing season, seed is planted only once, so the marginal cost of labour foregone to plant hybrid seed is negligible. In addition, the cost of fertilisers applied per hectare is considerably more than the cost of seed. Mean seed costs for all maize growers are 3,762 KES, compared to 6,135 KES for fertiliser, and the maximum value is more than twice as high for fertiliser than for seed.

Table 4

CRE double hurdle estimating demand for fertiliser and hybrid seed in maize production, including non-farm income and farm labour, low agricultural potential areas

	Fertiliser use		Hybrid seed	
	Binary	Ln (kgs)	Binary	Ln (kgs)
Fertiliser price	−0.032	0.033	0.022	0.024
	(0.02)	(0.044)	(0.016)	(0.02)
Seed price	0.0097	−0.036**	0.0082	−0.004
	(0.0067)	(0.015)	(0.0053)	(0.0066)
Grain price	−0.120**	−0.122	0.140***	0.0077
	(0.05)	(0.104)	(0.037)	(0.039)
Wage rate	−0.0061***	0.0035	−0.0039**	−0.0012
	(0.0023)	(0.004)	(0.002)	(0.0023)
Distance to fertiliser	0.0176			
	(0.0165)			
Distance to seed			0.0047	
			(0.012)	
Farm size	0.043	0.045	−0.016	0.0011
	(0.035)	(0.046)	(0.032)	(0.0312)
Education	0.102**	−0.048	−0.018	−0.074
	(0.048)	(0.071)	(0.039)	(0.046)
Young adults	0.173	0.114	0.00013	0.017
	(0.15)	(0.27)	(0.12)	(0.13)
Mature adults	0.51	−0.31	−0.053	−0.12
	(0.38)	(0.83)	(0.28)	(0.31)
2004	0.33	1.94**	−1.08***	0.13
	(0.43)	(0.83)	(0.36)	(0.38)
Rainfall	−0.006***	0.006	−0.0026*	0.0015
	(0.0019)	(0.0049)	(0.0014)	(0.0016)
Good soils	−0.27	0.29	0.055	−0.031
	(0.26)	(0.55)	(0.20)	(0.23)
Crop diversification	−0.17	−0.26	0.39	−0.025
	(0.66)	(1.07)	(0.48)	(0.52)
Non-farm income	−2.11e-05	1.31e-05	4.60e-06	3.61e-06
	(1.47e-05)	(3.22e-05)	(1.08e-05)	(1.17e-05)
Residual1	2.11e-05	−1.16e-05	−4.61e-06	−2.62e-06
	(1.47e-05)	(3.22e-05)	(1.08e-05)	(1.17e-05)
Farm labour	−7.33e-05**	0.00019**	−3.86e-05	4.80e-05*
	(3.60e-05)	(9.27e-05)	(2.65e-05)	(2.91e-05)
Residual2	5.61e-05	−0.00019**	3.91e-05	−6.08e-05**
	(3.45e-05)	(9.10e-05)	(2.64e-05)	(2.93e-05)
Constant	0.36	13.15***	−3.98**	2.98
	(2.07)	(4.53)	(1.56)	(1.84)
Observations	757	757	762	762
Wald chi 2 (23)	161.68		100.75	
Log likelihood	−444.56		−559.36	

Notes: Robust standard errors given in parentheses. ***$P < 0.01$, **$P < 0.05$, *$P < 0.1$.
Source: Authors.

The significance of the residuals in both input regressions suggests that income from working on other farms is endogenous in intensification decisions in agricultural areas with lower productivity potential. Interestingly, non-farm income is not significant or endogenous in either input decision. The high reliance of households on non-farm income in less productive agricultural areas, in general, may explain this result. That is, the relationship may be recursive: households may decide how much labour to allocate to non-farm activities first, pursuing more subsistence-oriented farm production with remaining resources. The subsistence orientation is suggested also by the negative effect of the grain price, which is theoretically consistent with the response of a net buyer of maize grain in a more isolated area.

5. Conclusions

The results of our analysis suggest differences in the impacts of off-farm earnings on input use and maize intensification across different inputs and off-farm activity types, and these differences are conditioned by productivity potential. The emerging picture is that, holding prices, other crops grown, locational and relevant household characteristics constant, off-farm earnings are inversely related to both fertiliser and hybrid seed use on maize in Kenya – most particularly in the higher potential agricultural areas where farms are commercialising, intensification of maize production is relative greater, and labour constraints are binding. Non-farm income explains most of this pattern. In the areas with lower agricultural potential, in contrast, extremely low quantities of fertiliser are used in maize production and our regressions shed far less light on the potential for intensification. Reliance on off-farm income is greater in these areas than in the more commercialised agricultural areas, and off-farm vs. intensification decisions appear to be made recursively, with maize production driven more by subsistence needs. One striking finding in these areas is the negative effect of earnings from agricultural wage labour (farm *kibarua*) on other farms on the likelihood of fertiliser use, and once used, the positive effect on hybrid seed and fertiliser amounts applied. Our interpretation is that these results reflect greater cost and labour constraints in fertiliser use than in seed use in maize production. Fertiliser is applied to maize when hybrids are grown, and hybrids are grown much less frequently.

Price effects are strong in all regressions, exhibiting the complementarity of seed and fertiliser use as inputs. In the higher potential agricultural areas, the positive effect of grain prices and the negative effect of wage rates are also evident, supporting the general picture of a commercial orientation in maize production. These findings support the conclusion that farmers respond to economic incentives in maize production, especially where yields and yield responses are like to be relatively good. By comparison, the negative coefficient on the grain price, combined with the negative coefficient on the wage rates in the lower potential areas is consistent with the expected behaviour of net buyers of maize who allocate a larger part of labour to off-farm activities. Distance to input dealers has no significant effect once we have controlled for prices and other factors, perhaps reflecting the fact that market infrastructure has improved over the years in Kenya. Input use is greater in villages where soils have more humus and organic matter. Education of the household head consistently has a negative effect on maize intensification, again consistent with past literature showing that returns to education are higher off-farm than on-farm, and more educated households as a result allocate more of their resources to off-farm activities.

This analysis provides empirical evidence of the dynamic changes in rural Kenya as some farms commercialise in the areas with high potential agricultural productivity, and others, particularly in lower potential areas, orient their income-earning strategies toward off-farm earnings and maize to meet subsistence needs only. Off-farm income, and specifically income from non-farm business, salaries, wages and remittances, competes with investment in maize production in the higher potential zone. The simultaneity of labour allocation decisions between the farm and non-farm sector is evident in our inability to reject the endogeneity hypothesis. Comparatively less explanatory power in the regressions for lower potential agricultural areas underscores the complexity of decision-making in those environments, as well as the fact that extremely low levels of fertiliser and hybrid seed were used. In these areas, labour allocation decisions between off-farm and farm sectors appear to be made recursively, with no impact of non-farm employment, although farm *kibarua* raises input use in maize.

Given the results of this study, further research on other major crops may help in generating clearer patterns. Additional important questions for future research would be whether off-farm earnings are reinvested in agriculture through purchase of farm capital, commercialisation or other non-income generating activities (e.g. education, health), which may also have an impact on farming and off-farm activities in the longer run. In addition, it might also be important to investigate how the household member earning the income affects its reinvestment into agriculture.

Supporting Information

Additional Supporting Information may be found in the online version of this article:

Table S1. Use of fertilizer and hybrid seed in maize production, by production environment and year

Table S2. CRE double hurdle models estimating demand for fertilizer and hybrid seed in maize production, including combined sources of off-farm income, all production environments

Table S3. CRE double hurdle models estimating demand for fertilizer and hybrid seed in maize production, including combined sources of off-farm income, higher agricultural potential areas

Table S4. CRE double hurdle models estimating demand for fertilizer and hybrid seed in maize production, including combined sources of off-farm income, low agricultural potential areas

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