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OFF-FARM WORK AND FARM PRODUCTION DECISIONS:EVIDENCE FROM MAIZE-PRODUCING HOUSEHOLDS IN RURAL KENYA

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Abstract

A major challenge facing farming in developing countries has been the need to raise farm incomes through increased agricultural productivity. One acceptable means has been the diffusion of new production techniques, especially use of chemical fertilizers, and high yielding varieties of seeds and pesticides. However, a major impediment to the adoption of such productivity-enhancing inputs has been the unavailability of liquid capital particularly cash to finance such expenditures. Another well-documented fact is the risk-averse nature of most rural decision makers in developing countries yet use of such modern inputs is likely to not only increase the expected returns, but the accompanying risks as well.

Despite these problems, both credit and crop insurance markets are lacking in most developing countries, thus limiting the use of these modern inputs. This difficulty is especially great for food crops, which lack the institutional arrangements that sometimes relieve credit constraints for cash crops. In the absence of credit facilities, farm practices especially those requiring capital may be dependent on existing sources of income. Under these circumstances, it is plausible that earnings from off the farm may often be used to compensate for the missing and imperfect credit markets by providing ready cash for input purchases as well as other household needs. In addition, off-farm earnings could be used to spread the risk of using these modern farm inputs. To the extent that farmers choose traditional over modern inputs in order to lower their risk, any mechanism that allows farmers to smooth consumption will raise the use of modern inputs and increase farm productivity.

This paper explores the extent to which off-farm work affects farm production decisions through reinvestment in farm input use and intensification. We estimate farm input demand functions for fertilizer and impoved seed for Kenyan maize producers. The results indicate differences in off-farm work effects across different inputs and off-farm activity types. While the results suggest possible use of off-farm earnings for input purchase especially for those without other forms of credit, the ‘combined’ input package seems to represent a substantially greater commitment and orientation, one possibly not attractive to those with higher off-farm earnings. Thus, while engagement in off-farm work may allow some partial intensification, it may also compete with farming at higher levels with households shifting their resources to other uses perhaps with higher returns than agriculture. We find the presence of a regular source of earnings to be the driving force behind any reinvestment behavior.

Key words: Off-farm work; Input intensification; Credit; Kenya

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CPI	Consumer Price Index
MPT	Modern Portfolio Theory
MVP	Marginal Value Product
OPV	Open Pollinated Variety
SSA	Sub-Saharan Africa

1.0 Introduction and Problem Overview

It has been widely argued that, during early stages of development and in societies where most of the population is composed of rural smallholder farmers as in much of Sub-Saharan Africa (SSA), increased agricultural productivity is necessary to increase incomes of most of the poor directly, and to stimulate the development of the rural non-farm economy (Timmer, 1984; Block, 1994; Reardon et al., 1994; Reinert, 1998; Byerlee et al., 2005). Without such impetus, broader growth in the rural economy will be constrained and poverty reduction much more difficult to achieve.

Three observations are noteworthy in this regard. First, agricultural productivity has stagnated in SSA and, in many instances, poverty is rising (World Bank, 2004). Productivity growth in the smallholder sector has been especially difficult to achieve. Second, research has shown that large minorities and, in some cases, majorities of households in rural Africa earn larger shares of their income from off-farm employment than they do from on-farm work (Reardon and Taylor, 1996; Reardon et al., 2000; Tschirley and Benfica, 2001). These findings point to the important role that off-farm employment can play in poverty reduction as enumerated in vast literature (Reardon, 1997; Lanjouw and Lanjouw, 2001; Barrett et al., 2001; Barrett et al., 2005). Finally, agricultural credit for smallholder farmers is severely lacking in most countries of SSA, making it difficult for poor farmers to finance the inputs typically needed for increased productivity (Carter, et al., 2004). This difficulty is especially great for food crops, which lack the institutional arrangements that sometimes relieve credit constraints for cash crops such as coffee, tea and cotton.

While the above studies and many more have made numerous contributions on the role of both farm and off-farm employment to poverty reduction, little is known about the exact nature of the interaction between these two sectors at the household level. Specifically, there exists minimal empirical literature on the relationship between off-farm work and agricultural productivity. At an aggregate level, the relationship between farm and off-farm sectors can be explained through growth of linkages whereby an increase in agricultural productivity increases agricultural output and incomes which spur growth in the non-farm sector (Reinert, 1998). While this is indeed very important for rural development, the design of specific pro-poor policies could benefit from more specific information on the nature of the interaction between farm and off-farm sectors at the household level.

The above observations raise the question of research in this paper: do off-farm earnings contribute to the financing of productivity enhancing investments in agriculture? If so, such income could help drive a "*virtuous circle*" of self-reinforcing growth and serve as an engine of rural transformation. If, on the other hand, off-farm income is primarily used for consumption, investment in household assets, and expansion of other off-farm activities, its contribution to agricultural transformation and thus to broad-based growth and poverty reduction in rural areas will be more limited.

With limited availability of credit for smallholder agricultural activities, productivity growth in the smallholder sector remains a major challenge. Under such circumstances, agricultural intensification may be reliant on cash generated within the household. According to Lamb (2003), households use off-farm work to mitigate the effects of production shocks, leading to greater use of fertilizer. He argues that, to the extent that farmers choose traditional over modern inputs to lower their risk, any mechanism (such as off-farm work) that allows farmers to smooth consumption can be expected to raise the use of modern inputs and increase farm productivity. Consistent with Lamb (2003), we argue apriori 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. These arguments are also consistent with those of Collier and Lal (1984), Reardon et al. (1994) and Barrett et al. (2001). According to Clay et al. (1998), greater off-farm income means more cash available to the household to invest on-farm.

A few earlier studies examining the interaction between farm and off-farm sectors in Africa have been empirical in nature (Collier and Lal, 1984; Haggblade et al., 1989; Savadogo et al., 1994; Clay et al., 1998). These studies look at different aspects of farm investment, and thus have found mixed evidence for the direction of off-farm work effects on farm investment. Savadogo et al. (1994) conclude that non-farm earnings do positively influence animal traction adoption. Clay et al. (1998) find a positive effect of non-cropping income on land conservation investments and an insignificant effect on use of chemical inputs. Reardon et al. (1994), using a capital market perspective, argue that the evidence on the interaction between farm and off-farm sectors is mixed and point to the lack of studies in Africa that explore the 'direction and nature of reinvestment' into the farm. A similar finding was later echoed by Clay et al. (1998).

More recently, analysts have begun to explore more rigorously these relationships. Some of the studies have looked at the effects of off-farm work on farm investment (Ahituv and Kimhi, 2002; Chikwama, 2004; Morera and Gladwin, 2006) while others have analyzed the impacts of off-farm work on various aspects of farm production decisions (Lamb, 2003; Dusen and Taylor, 2005; Phimister and Roberts, 2006). Though using different approaches and analytical tools, most of these studies, with the exception of Lamb (2003), indicate a negative relationship between off-farm work and agricultural investment/production.

Among those finding a positive relationship, Lamb (2003), finds that fertilizer demand in the semi-arid tropics of India increases with the depth of the off-farm labor market, thus suggesting some complementarities between the off-farm labor market and own-farm production. In addition, while studying poverty-environment patterns in Chile, Bahamondes (2003), concludes that 'non-farm employment permitted agricultural intensification' that in turn reduced pressure on the natural resource base. A similar finding was echoed by Gasson (1988) who suggested that off-farm work was frequently undertaken to finance debts on the farm, purchase machinery and other farm equipments in addition to other family needs (p.27). See Phimister and Roberts (2006) for a review of other arguments for the two alternative predictions.

In this study, we look at how off-farm earnings affect farm input use and intensification. As with Clay et al. (1998)[1], Lamb (2003) and Phimister and Roberts (2006), the paper analyzes the relationship between off-farm work and fertilizer use in addition to the use of improved seed for maize-producing rural households in Kenya. We however deviate from the above studies by looking at input intensification in a particular crop, maize, thus facilitating more concrete interpretation of results.

The study uses maize to explore this relationship for the following reasons. First, it is the most widely grown and locally traded crop in Kenya, with 98 percent of households outside of semi-arid areas growing it. Second, the crop uses substantial inputs in form of fertilizer and hybrid seeds and accounts for about 28 percent of gross farm output from the small-scale farming sector. Third, maize is far and away the main staple food in the country. Finally, there is hardly any organized credit system for maize (and most other annual crops), thus creating potential for use of other off-farm sources of cash to finance input purchases. This collection of facts suggests that increased maize productivity is likely to be an important goal for most households, and that maize will be among the first choices for many of them in deciding whether and how to intensify their agricultural production.

This paper adds to the literature in a number of ways. First, it is a contribution to the sparse body of literature that empirically examines the effects of off-farm work on agriculture. Among the studies reviewed in this paper, only Clay et al. (1998) and Chikwama (2004) were carried out in Africa where increased agricultural productivity is much needed and credit limited. Second, and in addition to the overall off-farm work effects, the paper distinguishes the effects of different types of off-farm work on agricultural intensification. Finally, by using a particularly rich data set, the analysis controls for a number of other relevant household and locational characteristics frequently omitted in other studies. In addition, we deal with the possible endogeneity of off-farm work, thus allowing identification of off-farm work effects.

[1] Clay et al (1998) analyzes the effects of non-farm income on an aggregate of chemical inputs which include fertilizer, pesticides and lime.

The paper is organized as follows. In section 2, we develop a conceptual model to motivate the rest of the paper and also outline the empirical strategy adopted in the study. Section 3 decribes the data used in the analysis. The econometric models to be estimated plus the specification and estimation issues are discussed in section 4. In Section 5, the results are discussed and summary and conclusions given in section 6.

2.0 Theory and Empirical Strategy

2.1 Conceptual Model

We consider a risk averse, single member household engaged in a portfolio of on-farm and off-farm activities. Returns from each activity are uncertain and imperfectly correlated. In a two period decision model[2], the household decides at period t=0 how to allocate its time and previously earned income. Earned cash can be spent on input purchases, on hired farm labor, 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), the household earns income and repays credit.

We define an on-farm production function $Q=Q(L^f, L^h, Z; A, H, G)$, where L^f is on-farm family labor, L^h is hired labor, Z represents a vector of purchased inputs, and A, H, and G are vectors relating to agro-ecological conditions, human capital, and other household and locational characteristics, respectively. H embodies both the skills and the orientation of the household. The household is endowed with a fixed quantity of labor time, $L=L^o + L^f$, where L^o represents off-farm labor. In a credit constrained world, credit (CR_0), cash allocated to off-farm activities (C^o), and the quantity of purchased inputs and hired labor are determined simultaneously. Purchased inputs and on-farm labor (both family and hired) are assumed to be complements in production[3].

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[2] We consider two periods, rather than n periods, to simplify the derivations that follow. This simplification should not affect the key implications from the model.
[3] While this is considered true for the kind of inputs referred to in this study, it is however not necessarily so for all other inputs. Herbicides are clearly an exception.

The household's objective is to maximize 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)[4], r is the household's risk-free discount rate, α is its risk premium, CR'_1 is the nominal value of repaid credit, and all other terms are as previously defined.

Incorporating the production function and time constraint, we have:

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

Where P_1^Q is output price, W_1^O is the off-farm wage rate[5], P_0^z is the price of inputs, W_0^h is the wage paid to hired labor, $C_0^O(\cdot)$ 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 get:

$$Z: \frac{P^Q \left(\frac{\partial Q}{\partial Z} + \frac{\partial Q}{\partial L^f}\frac{\partial L^f}{\partial Z} + \frac{\partial Q}{\partial L^h}\frac{\partial L^h}{\partial Z} \right) + W^O \frac{\partial L^O}{\partial Z}}{(1+r+\alpha)} - P^Z - W^h \frac{\partial L^h}{\partial Z} - \frac{\partial C^O}{\partial Z}$$

4 For ease of exposition, we do not distinguish between capital costs and variable costs for off-farm work.
5 We conceive this as a general term reflecting both wages and returns to labor in businesses operated by the household.

$$+\frac{\partial CR}{\partial Z}\left(1-\frac{1+r'}{1+r+\alpha}\right)-\lambda\left(\frac{\partial L^{O}}{\partial Z}+\frac{\partial L^{f}}{\partial Z}\right)=0 \quad (3)$$

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 up to the point 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 marginal value product of inputs without taking into account imperfections in labor and credit markets. We denote this 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 pp 251), we can represent the risk premium as:

$$\alpha = \left\lfloor E(r_{m}) - r_{f} \right\rfloor \beta_{j} \quad (5)$$

where:

$$\beta_{j} = \frac{Cov(r_{m} r_{j})}{Var_{m}} = \rho_{jm}\frac{\sigma_{j}}{\sigma_{m}} \quad (6)$$

Where r denotes a rate of return, subscripts m, j, and f refer to the portfolio, the investment/activity of interest, and a risk-free asset, respectively, 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 σ_j) and with its correlation with the existing portfolio (ρ_{jm}).

Terms two through four in equation (4) capture the effects of labor market imperfections. Examining the second term, the bracket is the risk adjusted discounted marginal value product of family labor on the farm minus the shadow wage rate. This value is multiplied by the marginal effect of inputs on family labor 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 optimize its time allocation. If non-zero, this term is decreasing in risk. The same logic applies to the third term: an optimizing household will not pay hired labor 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 in sub-Saharan Africa hire in farm labor, $\partial L^O / \partial Z$ for most households will (by the labor constraint) be comparable in absolute value to $\partial L^f / \partial Z$. As a group, therefore, we expect terms two through 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 for 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.

Note that including off-farm considerations, as captured in terms four (negative) and six (positive), has an ambiguous effect on input use.

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. 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 a greater orientation away from agriculture towards off–farm activities, which would tend to decrease input use efficiency.

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

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

2.2 Motivation and Empirical Strategy

From 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. Risk-averse households are likely to prefer portfolios with activities whose individual returns are uncorrelated or negatively correlated. 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 1) the expected returns from intensification (and their variance) as dictated by agro-climatic conditions and the household's aptitude for farming and 2) the correlation of those returns with the existing portfolio; of special 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. This is implied in equation (4) by the fact that for a given risk preference, different portfolio composition may lead to different levels of risk premium and thus different implications for input use. In this study, and guided by both data and the perceived levels of ρ_{jm}[6] hence β_j and α for different off-farm work types, we explore the impacts of three different types of off-farm earning activities, based on their stability and likely correlation between their returns and returns to agriculture: salaried labor/pension, remittances, and other business and service activities.

Salaried labor/pension: Salaried wage labor and pensions have relatively high returns, low risk and low correlation with earnings from agriculture: these activities are unlikely to suffer from shocks such as weather that impact farming, and will on average depend less on local demand (which is driven to a great extent by agricultural outcomes) than other types of off-farm activities. Thus, we expect households with salaried wage (part of portfolio m) to have a lower β_j and hence lower α as compared to households with informal business activities. For a given risk preference, expected return and activity mix,

[6] Data shows correlations of 0.1344, 0.0490 and 0.0298 of crop income with informal business, salaried wage and remittance income, respectively. Only the correlation with informal business is significant at 1% level.

households with salaried income may be more willing to take on the risk of modern inputs[7] than those with informal business and remittance income[8].

Remittances: 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. Overall, we expect this source of income to be more uncertain than income from salaries/pensions. However, specific impacts will depend on the above three issues and the expected returns from agriculture. For example, a salaried head of household living away from the family may remit higher amounts on a regular basis, hence facilitating investment into agriculture. Similarly, since remittances could come from an explicit strategy of migratory labor to spread risk over space, the low correlation of such earnings with local agriculture could imply potential reinvestment behavior into agriculture. Because we do not have information on the remitter and the activities they are involved in, the expected effects of this category remain an empirical question. 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: This classification includes several types of activities such as agricultural wages (typically seasonal, low wage work on neighboring farms), trade, manufacturing, and services. The expected returns, relative riskiness and correlation with agriculture may differ with specific activity types, but generally, the returns from these activities will be less stable than salaried wages. They are also more likely to depend on local demand, meaning that returns are expected to be correlated with

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[7] Though the use of fertilizer and improved seed is likely to increase both the expected returns and the variance of those returns, there are other important non-monetary gains from investing in farming such as food security which can affect the above expectations.

[8] The broader point is that salaried income will most likely allow investment in two types of activities: those with higher return and higher risk, and those with a longer time horizon, such as education or mortgage payments. Investment in hybrid seed and fertilizer is one example of the first type, but of course is not the only type of investment that will be more likely due to the presence of salaried income.

returns to the dominant income source in the area. Reinvestment of income from these activities into farming may thus be expected to increase with: 1) the share of off-farm earnings in total cash income in the geographical region, and 2) the expected returns from farming as determined by the agricultural potential of the region. However, given that low potential regions (with low expected returns from farming) tend to have high shares of off-farm income[9], the net effect of these counteracting forces becomes an empirical question.

3.0 Data

Data for this study were drawn from the Tegemeo Agricultural Monitoring and Policy Analysis Project (TAMPA) data set. It consists of a household level panel collected during the 1999/00 and 2003/04 cropping seasons by Tegemeo Institute, Kenya. The specific sample used in this study consists of 1832 observations i.e. 916 maize-producing rural households for each year. The households included in this analysis live in regions that have bimodal rainfall patterns, which enables the assessment of the impact of income earned in the previous season on current use of inputs within a given year (see later discussion on endogeneity). Because the "high potential maize zone" of the Rift Valley has a single cropping season (higher altitude means that maize takes much longer to mature), we were unable to use this part of the sample. The sample that we did use accounted for 66 percent of all farms, 45 percent of the total value of fertilizer use during 2003/04, and includes high potential areas such as the Central and Western Highlands, low potential areas such as the coastal, eastern, and western lowlands, and other medium potential areas. The data contains information on economic, demographic and other locational characteristics of the households.

Table 1 presents the description of variables used in this study including their means and standard deviations. The dependent variables include the binary input adoption variables and the intensity of use as given by the amount used per acre for both fertilizer and hybrid seed. Given the nature of the problem, we use off-farm earnings in place of wages

[9] Mean off-farm income shares for the low and high potential regions are 46% and 35% respectively. Much wider differences exist with more disaggregated data (see Table A1).

(w_o) as indicated in equation (7). Prices of inputs and all cash values are adjusted for inflation (to 2004) using the respective consumer price indices (CPI). The binary variable for agricultural potential was constructed based on agro-regional zones[10] as defined in the Tampa data set. Based on maize productivity in low- and medium-high altitude areas, the lowlands were assigned to the low agricultural potential areas while the highlands were put in the high agricultural potential areas.

[10] These agro-regional zones were coined by Tegemeo during sample design and are based on agro-ecological zones and population densities.

Table 1: Summary Statistics of Variables used in the Models

Variable Description	Type	Unit	Mean	Std Deviation
Adoption and intensity measures				
Fertilizer Amount	continuous	kg	14.5	32.19
Hybrid seed Amount	continuous	kg	2.4	5.16
Fertilizer adoption	binary	1/0	0.36	0.48
Hybrid Seed adoption	binary	1/0	0.31	0.46
Fertilizer and Seed adoption	binary	1/0	0.25	0.43
Monetary incentives				
Price of fertilizer	continuous	Ksh/kg	30.02	6.71
Price of hybrid seed	continuous	Ksh/kg	120.10	19.65
Price of other seed	continuous	Ksh/kg	28.30	31.43
Farm wage rate	continuous	Ksh.day	71.85	30.94
Price of maize	continuous	Ksh/kg	13.08	1.87
Presence of major cash crop	binary	1/0	0.29	0.45
Income sources(previous season)				
Agricultural cash income	continuous	Ksh(‘000)	33.07	58.48
Off-farm earnings	continuous	Ksh(‘000)	22.96	42.07
Informal income	continuous	Ksh(‘000)	9.60	24.13
Salary/pension income	continuous	Ksh(‘000)	12.02	30.75
Remittances	continuous	Ksh(‘000)	1.33	5.23
Public infrastructure				
Distance (fertilizer seller)	continuous	km	3.96	5.62
Distance (seed seller)	continuous	km	3.68	4.86
Agro-ecological conditions				
Main (planting) season	binary	1/0	.26	.44
Agricultural potential	binary	1/0	.48	.49
Long-term rainfall mean	continuous	mm	946.19	256.85
Demographics				
Age of head	continuous	years	55.27	13.51
Male head of household	binary	1/0	.81	.39
Number of adults	continuous	count	4.72	2.30
Primary education	binary	1/0	.37	.48
Access to credit				
Group membership	binary	1/0	.82	.38

No. of Observations=1832

Group membership is a binary variable representing whether a household belonged to a farmer cooperative/group or not. We use this variable to proxy for access to credit given that nearly all agricultural credit was received through cooperative societies: in the 2003/04 survey, 96 percent of those who received agricultural credit were members of a cooperative society.

The table shows that about 36 percent of households in our sub-sample used fertilizer and 31 percent used hybrid seed, while about 25 percent used both inputs during the period under consideration. Table 2 clearly shows that adoption rates for hybrid seed and the combined package are lower for those households with off-farm work (any type) than for those without. A similar pattern is observed for fertilizer though the difference in means is not significant. When disaggregated by type of off-farm work, informal business and remittances follow a pattern similar to overall off-farm work. This is in contrast to the pattern that emerges with salaried wage and pension. We observe a higher proportion of households using both fertilizer and hybrid seed for those households with salaried wage and pension than for those without.

Table 2: Fertilizer and Hybrid Seed Use by Type of Off-farm Work

Type of off-farm work	Fertilizer		Hybrid Seed		Fertilizer and Hybrid Seed	
	Adoption (% of hhs)	Intensity (kg/acre)	Adoption (% of hhs)	Intensity (kg/acre)	Adoption (% of hhs)	Intensity (Ksh/acre)
Any off-farm work						
No	0.39	43.65	0.36	7.84	0.28	2466
Yes	0.36	38.40	0.30	7.63	0.24	2387
t-value	1.17	1.34	2.18**	0.32	2.03**	0.29
Salary/pension						
No	0.34	40.86	0.30	8.02	0.23	2515
Yes	0.43	37.67	0.34	7.03	0.29	2218
t-value	-3.60***	0.96	-1.85*	1.91*	-2.82***	1.28
Informal/business						
No	0.41	40.94	0.35	7.58	0.29	2344
Yes	0.32	38.27	0.27	7.82	0.21	2492
t-value	3.59***	0.80	3.61***	0.43	3.77***	-0.56
Remittances						
No	0.37	40.79	0.32	7.77	0.26	2436
Yes	0.36	35.53	0.27	7.32	0.20	2272
t-value	0.33	1.29	2.02**	0.62	2.29**	0.54

N/B: Quantity figures represent amount of inputs used among those using. The t-value represents the tabulated t for the difference in the means for each respective category while *** significance at 1%, ** significance at 5% and * significance at 10%

Fertilizer and Hybrid Seed Use in Kenya

In the past, Kenya has been categorized as a high cost maize producer relative to neighboring countries such as Uganda (Nyoro et al., 2004). Among the reasons for this lack of competitiveness are high cost of farm inputs, low seed quality and a weak extension system. Nyoro et al. (2004) show that fertilizer and seed expenses account for about a third of the total cost of production for most production systems. Yet previous studies (mostly using this data set) have clearly shown that fertilizer use remains profitable in most agricultural areas of Kenya (See Wanzala et al., 2001 for a brief review of these studies). In addition, data presented in Muyanga et al. (2005), show relatively high productivity of fertilizer on maize (maize output/kg of fertilizer) even for the lowland areas. Although maize is the most fertilized crop, intensity of use tends to be less than on high-value and export crops (Nyoro et al, 2006), a factor that has been identified as limiting maize productivity. This has called for an effective extension system to educate farmers on the appropriate fertilizer types and recommended levels of use.

One of the factors hampering the adoption of hybrid seed and its relative profitability has been a decline in seed quality (Nyoro et al., 2004; Ayieko and Tschirley, 2006). This is suggested also in the TAMPA data set, which shows declining use rates and intensity for hybrid seed between 2000 and 2004[11]. According to Ayieko and Tschirley (2006), a large share of seed used in Kenya is from the informal sector with no clear certification procedures. This scenario has potential for opening up room for production of low quality seeds, an issue that not only raises the relative cost of production as yields decline, but also acts as disincentive to use of improved seed.

It is also possible that hybrid seed is being used in areas less suited to its use. It has been shown that a higher maize output per unit of seed can be achieved in some regions like the lowlands and some of the highlands when open pollinated seed varieties (OPV) are used as compared to hybrid seed (Muyanga et al., 2005). Also, in comparing Ugandan and Kenyan maize production systems, Nyoro et al. (2004) concluded that Ugandan households achieve higher profitability using OPV and lower levels of fertilizer than their Kenyan counterparts who mainly used hybrid seed and higher levels of fertilizer. Though it would have been insightful to estimate input demand functions for OPV, the limited number of cases available thwarted any such efforts. Only about 10% of reported seed type was OPV. Local varieties formed about 37% of the total reported cases.

4.0 Model Specification and Estimation

4.1 Econometric Model

Input demand functions based on equation (7) were modeled to determine the factors that drive farmer's decision to use inputs and to assess how engagement in off-farm work affects this decision. Separate regression models for fertilizer and hybrid seed are

[11] Adoption of hybrid seed for our sample households declined from 35% to 28% (8.4 kgs to 6.7 kgs for intensity among those using) between 2000 and 2004.

estimated, each with aggregated and disaggregated off-farm work types. The timing of cash flow from the off-farm sector and farm input requirements are harmonized by considering the impact of past earnings on current use of farm inputs. To ensure identification of the coefficients of interest, we control for the economic incentives facing the households, household resource endowments, investment in public infrastructure, credit availability, other income sources and agro-ecological and locational characteristics of households.

Input prices were included to control for variations in input use as a result of changes in economic incentives facing households. We included the previous season's price of maize based on a naive expectations model of farmer decision making. Previous cash income from agriculture is included as a control for other potential sources of income to finance input purchases, and also to capture the household's capacity and orientation towards agriculture. Presence of a major cash crop[12] in the household was included to capture how this affects input intensification of food crops like maize. Distance to the respective input seller was included to proxy for the cost of transport from the input supplier to the farm.

The data used in this study run across areas of differing agricultural potential and planting seasons; we include dummies to allow for the regression intercept to vary across each. We expect input use to be higher during the 'main' season and in the high potential areas as discussed in section 2.1. The inclusion of the long term (village) rainfall variable helps control for heterogeneity within zones of broadly comparable agricultural potential.

To control for the availability of inputs through credit, we use membership in a cooperative society or any such group as discussed earlier. It is noteworthy that these groups tend to provide inputs on credit to cash crop growers, but experience has shown that there is a spillover effect to cereal and other food crops. It is therefore expected that households that are members of a group will have a higher likelihood of using these

[12] Major cash crops include tea, coffee and sugarcane, all of which involve long term investments that households cannot easily move in and out of.

modern inputs and may use them more intensely when they do. The period dummy is equal to one for 2004 and captures any trend in input use as a result of external factors common to all households.

We control for household resource endowments and characteristics using the education, gender, and age of the head of household. Education is captured in a dummy variable for whether the household head had acquired a primary school education or not. We control for experience using age and include gender (male headedness) to assess whether and how the regression intercept changes between male and female head of household, who is assumed to make decisions on input use. Consistent with other studies (Lamb, 2003), our conceptual model assumes that input use and farm labor are complements[13] in production, thus we include number of adult household members to control for labor availability.

The model allows the coefficient of off-farm work to differ across agricultural potential, group membership and households with and without primary education. With the exception of the interaction with group membership, we cannot form clear apriori expectations on the other two variables, for several reasons, First, while education may imply more specialization in off-farm work, the ability to get 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 (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 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. Further, given the argument presented earlier, we expect households with some group membership and hence access to some credit, to rely less on their off-farm earnings to finance farm intensification.

[13] Though not much additional labor would be needed during planting, demand for harvest and topdressing (if any) labor would clearly go up. Also, timely weed control is a critical factor affecting fertilizer profitability.

Following the above discussion, the basic model for estimation is given by:

$$\mathbf{Z_{its} = \beta_0 + \beta_1 OFE_{its\text{-}1} + N_{its\text{-}1}\beta_2 + M_{its}\beta_3 + \gamma I_{its}{*}OFE_{its\text{-}1} + \delta_0 d04_t + \varepsilon_{its}} \quad \mathbf{i= 1,..,N\ t=1,2\ \ S=1,2} \quad \mathbf{(8)}$$

Where Z_{its} represents different aspects of input intensification namely fertilizer and hybrid seed use per acre for household i in period t and season s. OFE_{its-1} represent previous season's off-farm earnings, N_{its-1} include variables that control for other sources of income in the previous season, M_{its} is a vector of all other exogenous variables affecting Z which includes input prices, characteristics of the head of household, distance variables, group membership and other locational and agro-ecological characteristics of the household, I_{its} include variables in M that are interacted with off-farm earnings; $d04_t$ is a time period dummy and ε_{its} is the composite error term.

4.2 Specification Issues

Zero-expenditure (non-adoption)

If every household in the sample were observed to have used the respective inputs, estimation of model (8) would have been achieved through the standard panel data methods (fixed or random effects). However, Table 1 showed that only 36% and 31% of households used fertilizer and hybrid seed, respectively. Equation (8) can thus be visualized as a latent variable[14] model given by:

$$\mathbf{Z^*_{its} = \beta_0 + \beta_1 OFE_{its\text{-}1} + N_{its\text{-}1}\beta_2 + M_{its}\beta_3 + \gamma I_{its}{*}OFE_{its\text{-}1} + \delta_0 d04_t + \varepsilon_{its}}$$

Such that $Z_{its} = Z^*_{its}$ if $Z^*_{its} > 0$ and

$Z_{its} = 0$, otherwise

Thus our model becomes:

[14] Unlike in sample selection problems, we place less emphasis on the latent variable in such a corner solution outcome given that our interest is in the conditional expectation of Z (Wooldridge, 2002 pp.520)

$$\mathbf{Z_{its} = max\ (0,\ \beta_0 + \beta_1 OFE_{its-1} + N_{its-1}\beta_2 + M_{its}\,\beta_3\ + \gamma I_{its}{*}OFE_{its-1} + \delta_0 d04_t + \varepsilon_{its})} \quad \mathbf{(9)}$$

Model (9) defines the usual Tobit model. This model however suffers from a major limitation in that it postulates that the decision to use an input and the amount used are defined by a single mechanism (Wooldridge, 2002). 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. The specification enables the modeling of two separate decisions in this case: the decision to use an input and the intensity of use. To observe a positive level of input use, the model postulates that two separate hurdles must be passed. First, the household must decide to use the input or not, and second, conditional on the first hurdle, the household allocates some cash to purchase a specified amount of the input. Model (9) can thus be defined using two latent variables, Z^*_{its1} and Z^*_{its2}:

$$\mathbf{Z^*_{its1} = X_{its}\pi + \mu_{its}} \quad \mathbf{(10)}$$

$$\mathbf{Z^*_{its2} = Y_{its}\,\lambda + \eta_{its}} \quad \mathbf{(11)}$$

Where $\mathbf{Z^*_{its1}}$ denotes the unobservable individual household propensity to use the respective input as defined by a Probit model and $\mathbf{Z^*_{its2}}$ is a latent variable that describes the intensity of input use. X and Y represent the vectors of explanatory variables that affect the two decisions as given in model (8). μ_{its} is assumed to be distributed as N(0,1) and η_{its} as $N(0, \sigma^2)$.

Endogeneity:

We can potentially envision simultaneity of 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 labor. In addition, involvement in off-farm work could compete for labor and capital with farming activities especially where input markets are missing.

To eliminate these potential endogeneity problems, we consider the impact of off-farm earnings during the previous season on current farm input use and intensification.

Given the difficulties in controlling for unobserved heterogeneity in non-linear models like the ones in this study, we can expect potential biases in some of the estimated parameters, especially for those variables that may correlate with the farmer's innate ability and unmeasurable land characteristics e.g. inherent soil quality that may impact on input use. One such variable would be education, whose coefficient may have an upward bias, but given that this coefficient remains insignificant (see results below), the impact of this bias may be limited. The coefficient of agricultural cash income may be positively correlated with soil quality which may negatively affect input use; the coefficient on agricultural cash income may thus be biased downward. Yet this coefficient is positive and significant, implying that any bias is insufficient to reverse this basic result.

4.3 Estimation

There are two formulations of the double hurdle model depending on the assumed distribution of the second stage. Using the value of the log-likelihood, we rejected the log-normal formulation in favor of the truncated normal regression. The advantage of the truncated normal distribution version or the so called hurdle model of Cragg (1971) is that it nests the usual Tobit, thus allowing us to test the Tobit formulation hypothesis. Given the results of the likelihood ratio (LR) test in Table A2, the Tobit model specification is rejected in both fertilizer models but not in the hybrid seed models. Failure to reject the Tobit model implies that the Tobit results are not significantly different from when the assumed restrictions do not hold and is thus equally well specified for the hybrid seed models.

Under alternative assumptions, the two stages of the double hurdle model can be estimated separately or jointly. Estimation of the two stages separately is based on the assumption that there is no correlation between the errors in the two stages implying that the two decisions are made independently of each other. The LR test for this hypothesis strongly rejects the composite model in favor of joint estimation which allows for correlation between the two stages (see Table A3).

Following the discussion above, each of the two stages of input demand functions for fertilizer and hybrid seed were estimated jointly using maximum likelihood estimation (MLE) procedures. 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[15]. These findings are consistent with those of Ariga et al. (2006).

5.0 Empirical Findings and Discussion

Tables 3 and 4 present the joint MLE parameter estimates of both stages of fertilizer and hybrid seed demand, respectively, using aggregated off-farm earnings. Given the failure to reject the Tobit hypothesis in the hybrid seed models, we report the Tobit and Double Hurdle results side by side and compare them. The differing results between the two models support the hypothesis that fertilizer adoption decisions are driven by different mechanisms from the intensity decision. This is especially so for variables like cash crop, previous agricultural cash income, planting season, primary education, and gender of head, all of which show clear differences in their impacts between the double hurdle and Tobit model. For example, having a male head seems to positively influence the decision to use fertilizer but has no impact on the level used. On its own, the Tobit model predicts an overall positive but insignificant impact of male headedness on fertilizer use. In the hybrid seed model, estimates for this coefficient are more similar across Tobit and Double Hurdle, as they are with the education variable.

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[15] The mean land cultivated for this sample is about an acre, implying relatively low amounts of fertilizer and hybrid seed purchases (recommended DAP fertilizer and hybrid seed per acre are 50-75kg and 10kg respectively). In addition, the distance variable turns out insignificant in the intensity models.

It is noteworthy that both Tobit and double hurdle models deliver comparable estimates for off-farm work effects in both fertilizer and hybrid seed models. Overall, the Tobit model estimates are more comparable to the double hurdle estimates in the hybrid seed model than in the fertilizer model. This evidence, plus the general failure to reject the Tobit specification in the hybrid seed models, is not unexpected, given the fact that we expect much lower variability of hybrid seed use per acre, compared to fertilizer. This indicates a possible domination of the adoption decision over the intensity one and thus no significant difference in the two decisions. Table A4 offers statistical support for this argument: the coefficient of variation for the value of fertilizer use per acre (among those using) is 1.59, while that for hybrid seed is 0.88[16].

Given the above, we now focus on the double hurdle results, paying special attention to the off-farm work effect and its interactions with primary education, agricultural potential and group membership. We first discuss the results using the aggregated off-farm earnings (Model set I) and then briefly with the disaggregated off-farm work types (Model set II). By and large, the results of the two sets of models are plausible with quite stable coefficient estimates between the aggregated and the disaggregated models. A few key points are however worth noting:

First, the results of the test for the Tobit hypothesis have implications for the estimation methods used, especially for fertilizer. The strong evidence of rejection for the restrictions implied by the Tobit model may cast doubts on estimation results that assume a single mechanism for both the adoption decision and the intensity of use. This underscores the importance of using appropriate estimation methods.

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[16] For input quantities, the coefficient of variation is greater than one in nearly all cases of fertilizer and less than one for hybrid seed.

Table 3: Double Hurdle and Tobit Estimates for Fertilizer Demand (Aggregated Off-farm)

	Double Hurdle		Tobit
	Adoption	Intensity	
Price of Fertilizer	-0.1007**	-0.0599***	-1.3511**
	(2.22)	(5.04)	(2.46)
Price of hybrid seed	-0.0032	0.0048	-0.1231
	(0.15)	(1.33)	(0.68)
Price of other seed	0.0113**	-0.0001	0.1180**
	(2.02)	(0.07)	(2.27)
Daily Wage rate for farm labor	-0.0127**	0.0003	-0.2586***
	(2.19)	(0.19)	(3.69)
Price of maize (s-1)	-0.1461*	-0.0247	1.5516*
	(1.91)	(1.51)	(1.95)
Presence of major cash crop	0.8479	0.3619***	16.4725***
	(1.45)	(3.96)	(3.26)
Agricultural cash income(s-1)	0.0142***	0.0026***	0.0071
	(3.24)	(3.55)	(0.26)
Off-farm earnings(s-1)	0.0673***	0.0134***	0.4852***
	(2.65)	(2.92)	(2.76)
distance to fertilizer seller	-0.1268***		-3.4813***
	(3.80)		(4.91)
Main planting season	2.7515***	-0.1296	33.3545***
	(3.19)	(1.62)	(7.01)
Agricultural potential	3.8146***	1.1250***	62.4628***
	(6.62)	(10.84)	(11.80)
Long term yearly average rainfall	0.0003	0.0002	-0.0195*
	(0.20)	(1.21)	(1.82)
Age of head	-0.0292**	-0.0177***	-0.4974***
	(2.29)	(7.61)	(3.64)
Male head of household	1.0920**	0.0501	4.6362
	(2.57)	(0.58)	(0.98)
Number of adult members	0.0015	0.0383***	0.9943
	(0.02)	(2.73)	(1.31)
Primary education	-0.0614	-0.1308*	2.0041
	(0.14)	(1.75)	(0.48)
Group Membership	2.0549***	0.4979***	25.4065***
	(4.29)	(4.11)	(3.99)
2004 period dummy	0.2349	-0.4486***	10.5849*
	(0.45)	(3.06)	(1.67)
off-farm*primary	-0.0031	-0.0009	0.0200
	(0.34)	(0.73)	(0.29)
off-farm*agric potential	-0.0036	-0.0022	0.0365
	(0.51)	(1.57)	(0.51)
off-farm*group membership	-0.0662***	-0.0109**	-0.5677***
	(2.61)	(2.42)	(3.25)
Constant	4.2869	4.7740***	0.7628
	(1.03)	(5.76)	(0.02)
Observations	1832		1832

Absolute z statistics in parentheses; * significant at 10%; ** significant at 5%; *** significant at 1%

Source: Author's study

Table 4: Double Hurdle and Tobit Estimates for Demand for Hybrid Seed (Aggregated Off-farm)

	Double Hurdle		Tobit
	Adoption	Intensity	
Price of fertilizer	-0.1390***	-0.0443***	-0.1783
	(4.50)	(3.84)	(1.64)
Price of hybrid seed	0.0032	0.0011	0.0138
	(0.44)	(0.35)	(0.39)
Price of other seed	0.0088**	0.0024	0.0046
	(2.45)	(1.55)	(0.40)
Daily wage rate for farm labor	-0.0011	-0.0009	-0.0342**
	(0.33)	(0.55)	(2.52)
Price of maize (s-1)	0.1196***	0.0104	0.4809***
	(3.11)	(0.61)	(3.21)
Presence of major cash crop	0.4934	0.0904	4.0627***
	(1.50)	(0.82)	(4.08)
Agricultural cash income (s-1)	0.0045**	0.0000	0.0029
	(2.26)	(0.06)	(0.60)
Off-farm earnings (s-1)	-0.0015	-0.0028	-0.0029
	(0.18)	(0.68)	(0.07)
distance to hybrid seed seller	-0.0783***		-0.2663***
	(3.26)		(2.58)
Main planting season	1.3895***	-0.2487***	7.5674***
	(3.86)	(3.04)	(8.36)
Agricultural potential	1.9443***	0.4922***	9.7837***
	(7.48)	(4.44)	(9.77)
Long-term yearly average rainfall	0.0008	-0.0003	0.0004
	(1.19)	(1.27)	(0.20)
Age of head	-0.0082	-0.0042	-0.0678***
	(1.16)	(1.40)	(2.59)
Male head of household	0.5595**	0.2459***	1.9199**
	(2.50)	(2.59)	(2.08)
Number of adult members	0.0254	0.0307**	0.1660
	(0.66)	(2.02)	(1.13)
Primary education	-0.3034	-0.0209	-0.9143
	(1.37)	(0.25)	(1.15)
Group Membership	0.8108***	0.2285*	3.7035***
	(2.89)	(1.80)	(3.07)
2004 period dummy	-1.8059***	-0.8286***	-2.0115
	(5.20)	(5.95)	(1.63)
off-farm*primary	0.0032	-0.0007	0.0118
	(0.90)	(0.60)	(0.86)
off-farm*agric potential	0.0062*	0.0024	0.0220
	(1.82)	(1.40)	(1.41)
off-farm*group membership	-0.0071	-0.0007	-0.0343
	(0.91)	(0.19)	(0.86)
Constant	1.0163	3.3467***	2.3001***
	(0.50)	(4.35)	(70.33)
Observations	1832		1832

Absolute z statistics in parentheses; * significant at 10%; ** significant at 5%; *** significant at 1%

Source: Author's study

Second, because of the interaction terms, the coefficients on off-farm earnings reflect the effect of that income among households whose heads did not complete primary education, who live in lower potential agricultural areas, and who are not members of any cooperative or group. The coefficients on the interaction terms show how the above off-farm work effects differ for households with primary education, those in the high potential areas, and those with group membership. Results for the combined effects of primary education, agricultural potential and group membership and their significance are also presented.

Third, the variables for cash earnings from agriculture and from off the farm each embody two factors which can influence household decisions on agricultural intensification. First, they directly capture cash availability with which to purchase the inputs. Second, each variable reflects past decisions of households regarding how to allocate their resources and captures the learning that resulted from these decisions. Households with high incomes from off-farm activities are likely to have a stronger orientation towards them and a greater level of knowledge useful in such activities. Likewise, those with high cash income from agriculture are likely to have a stronger orientation towards agriculture and to have developed greater capacity for it as a result. Indeed, a household's agricultural cash income may reflect the overall strategy and orientation towards cash crops and production for the market in general.

Finally, most of the households using hybrid seed tend to also use fertilizer (see Table A4). Thus, while the two inputs are likely complements, the use of hybrid seed more often implies the use of a broader input *package* and thus may be a stronger indicator of intensification than is the simple use of fertilizer. The effects of this difference between the two inputs are clear in the data and are discussed in the results. In addition, and as discussed in the beginning of this section, fertilizer use per acre is more variable than is hybrid seed use. This difference again presents itself in the various results to which we now turn.

From Table 3, previous off-farm earnings have a positive effect on both the adoption of fertilizer and the intensity of its use. This implies that, in general and holding other factors constant, households with higher previous off-farm earnings have a higher probability of using fertilizer and use more when they do. In this case, off-farm earnings could be viewed as acting to relax the cash constraint on fertilizer use.

The presence of a household head with primary education does not affect the probability of using fertilizer. It does however affect negatively (at 10% significance), the intensity of use. As expected, households in the high potential areas tend to have a higher probability and intensity of using fertilizer. This is because of the expected higher returns to input use in these regions compared to the lower potential areas. The results in Table 3 and 5 (below) clearly show that fertilizer adoption and use is greater and highly significant in high potential areas (3.8146 for adoption and 1.1250 for intensity), but that the (still positive and significant) effects (3.7319 and 1.0745 respectively) are slightly less at mean levels of off-farm earnings. Membership in a group seems to increase significantly the probability of using fertilizer and the intensity of use, an observation consistent with expectations.

Table 5: Wald Test for the Combined Effects in the Fertilizer Models (Aggregated Model)

	Adoption Model			Level Model		
Variable	Combined Effect	Wald Stat	p-value	Combined Effect	Wald Stat	p-value
Primary education	-0.1326	0.02	0.8792	-0.1515	3.18	0.0744
Agric potential	3.7319	44.04	.0000	1.0745	117.15	.0000
Group Member	0.5349	18.15	.0000	0.2476	12.81	.0003

Source: author's study

It is important to note that the positive effect of off-farm work on the probability and intensity of using fertilizer does not vary significantly with education of head. In addition, the hypothesis that the impact of off-farm work varies across agricultural potential is rejected for both fertilizer adoption and intensity models. The coefficient of this interaction term is insignificant in both models.

The impact of off-farm earnings varies significantly between households with membership in a farmer group and those without such membership. The results in Table 3 show that households belonging to a group are much less likely to allocate their off-farm earnings to fertilizer adoption and allocate less when they do. In fact, the coefficient of off-farm income in fertilizer adoption nearly vanishes for households with group membership (.0673-.0662) implying that the positive off-farm effects on fertilizer adoption are minimal for such households. This is plausible given that group membership, especially in producer cooperatives, is a major source of credit or direct receipt of inputs for agricultural production. In this case, off-farm earnings may not be needed to relieve cash constraints for input purchase.

The high and significant off-farm work effects on fertilizer adoption for households without group membership imply that off-farm income relieves credit constraints to agricultural intensification within such households. This result is consistent with findings from Chile that 'targeted credit' (and off-farm employment) help to overcome the capacity barrier allowing increased agricultural intensification and reduced overgrazing (Swinton et al., 2003). Note that the coefficient on the intensity model is also positive, implying that once the decision to adopt has been made, the off-farm work effects on fertilizer intensity remain positive for both group and non-group members though clearly reduced for group members.

For hybrid seed models, the impact of previous off-farm earnings is insignificant in both the adoption and intensity models (See Table 4). This implies that increased off-farm earnings have no impact on hybrid seed use in maize. While this result is clearly surprising given the fertilizer result, our data does however shed some light. First, Table A4 in the appendices shows that, while only 68% of households that used fertilizer also used hybrid seed, about 80% of hybrid seed users also used fertilizer. These differences are more pronounced in 2004, when only about 59% of households using fertilizer also used hybrid seed compared to 85% of hybrid seed users who also used fertilizer. These results may indicate that, for most households, the use of hybrid seed implies using fertilizer as well, a combination which may imply *deeper* crop intensification and orientation in maize, and one possibly not attractive to those with higher earnings from off-farm work.

The argument above is partly supported by the regression results of the Probit model on the combined use of both inputs presented in Table A5. These results show that previous off-farm earnings have no significant impact on current use of the combined fertilizer and hybrid seed package. The implication could be that while households may be willing to invest their off-farm earnings into partially intensifying their maize through use of some fertilizer, using fertilizer plus hybrid seed may represent a substantially greater commitment and orientation in maize. This argument is indicative given that the coefficient of agricultural cash income is positive and significant in the hybrid seed adoption model.[17] This coefficient is also significant in the combined fertilizer and hybrid seed adoption model (Table A5). It is thus possible that only those households with a strong orientation towards agriculture, and more specifically toward market oriented crops, are willing to invest in hybrid seed.

It is also noteworthy that hybrid seed use and intensity declined over the study period, implying that our hybrid seed models could be missing out on some important factors that could have contributed to the decline. An example here could be the limited supply of certified hybrid seed and the growth of informal seed marketing that have resulted in declining quality of seed as earlier discussed.

The education variable remains insignificant in the two hybrid seed models which is consistent with earlier findings. As expected, and holding other factors constant, households in the high potential areas have a higher probability of using hybrid seed, and

[17] That this coefficient remains insignificant in the hybrid seed intensity model is not surprising as earlier discussed.

use more intensely (plant at higher density) when they do. As shown in Table 6, these effects change minimally at mean levels of off-farm earnings.

Table 6: Wald Test for the Combined Effects in the Hybrid Seed Models (Aggregated Models)

	Adoption Model			Level Model		
Variable	Combined Effect	Wald Stat	p-value	Combined Effect	Wald Stat	p-value
Primary education	-0.2299	1.87	0.1713	-0.0369	0.04	0.8333
Agric potential	2.0866	56.74	.0000	0.5473	20.34	.0000
Group Member	0.6478	8.46	.0036	0.2124	3.09	.0788

Source: Author's study

As with fertilizer models, the coefficient of off-farm work in hybrid seed models does not vary significantly with education. This is not surprising given that off-farm work and education variables are both insignificant in the adoption and the intensity models. The off-farm work effect does however vary across agricultural potential for the adoption of hybrid seed (at 10% significance level). Households in the high potential areas have a higher probability of allocating their off-farm earnings to using hybrid seed compared to their counterparts in the lower potential areas.

The impact of off-farm earnings on hybrid seed use and intensification does not significantly differ with group membership as in the fertilizer models. This result is not surprising given that most cooperatives deal with cash crops where fertilizer is the key input and opportunities do exist for diverting this fertilizer to maize and other food crops. Since hardly any such groups are specific for maize nor provide hybrid maize seed, belonging to a group is less likely to have a bearing on whether off-farm earnings are allocated for hybrid seed purchase. It is however plausible that belonging to a group may ease the financial constraints on the entire input purchase allowing households to more easily purchase those inputs not offered by the cooperatives. This is consistent with our finding that, on its own, group membership significantly increases both the probability of using hybrid seed and the intensity of use.

To identify the impact of off-farm earnings on input intensification, it is important to control for other sources of cash income that could potentially be used to finance input purchases. The variable for cash earnings from agriculture in the previous season has positive and significant effects in all the models except intensity of hybrid use as previously discussed. This implies that households that earn high incomes from farming tend to continue to earn more through modern input use and intensification. In addition, households with major cash crops tend to intensify more in their maize production. This is evident given the highly significant and positive coefficient of cash crop in the fertilizer intensity models. This coefficient is also nearly significant in both fertilizer and hybrid seed adoption models. This finding is consistent with earlier studies that find a positive relationship between cash and food crop intensification within households (see discussions on this in Kelly et al., 1996; Govereh and Jayne, (1999); Freeman and Omiti, 2003).

As expected, distance to the nearest input seller negatively and significantly influences the probability of using each of the inputs. It is noteworthy, however, that the average distance to the nearest fertilizer seller has declined from 4.7 km in 2000 to 3.2 km in 2004 and from 4.5 to 2.9 for hybrid seed which could be a result of improved input delivery systems after liberalization, a point well advanced by Freeman and Omiti (2003) and Ariga et al. (2006).

Most of the other variables we used as controls generally behaved as expected, with a few exceptions. The price of fertilizer was found to negatively and significantly influence its adoption and intensity of use, and also that of hybrid seed. This is plausible given that most households using hybrid seed also used fertilizer; while the fertilizer adoption decision can be made independently of the hybrid decision, use of hybrid seed typically implies the use of fertilizer. The price of hybrid seed however remains insignificant in both the fertilizer and hybrid seed models. Price of other seed was expected to be positive in hybrid seed and most likely in fertilizer regressions (for both adoption and levels). The results meet these expectations in both adoption models and remain insignificant in the intensity models. The previous season's maize price is positive and significant in the hybrid seed adoption model and has no impact on the intensity of hybrid seed. That this coefficient remains negative and significant in the fertilizer adoption model is both puzzling and an issue of further investigation.

The main season variable is positive and significant in both adoption models as expected, but it turns out negative and significant in the hybrid seed intensity model. While it may be possible that households tend to follow recommended input rates when the weather is unfavorable than when it is, this result may also reflect the fact that the planting season variable only runs across regions given the inability to use data for both seasons from the same households. Long-term mean rainfall is insignificant in both fertilizer and hybrid seed models. While this may seem unexpected, it is possible that its effects are captured through related variables like agricultural incomes, the season variable, and agricultural potential.

As expected, the number of adult household members positively and significantly influences the intensity decisions in both fertilizer and hybrid seed models. Other characteristics of the household, for example, age and gender of the head generally behaved according to expectations.

Tables 7 and 8 present the regression results with disaggregated off-farm earnings as described in section 2.2 (the results of the combined effects are presented in Table A6 in the appendices). This analysis was done to identify which of the different types of off-farm work drives reinvestment decisions. As mentioned earlier, other coefficients remain relatively stable across the aggregated and disaggregated models.

Table 7: Double Hurdle and Tobit Estimates for Fertilizer Demand (Disaggregated Off-farm)

	Double hurdle		
	Adoption	Intensity	Tobit
Price of fertilizer	-0.1008**	-0.0587***	-1.3221**
	(2.21)	(4.88)	(2.40)
Price of hybrid seed	-0.0125	0.0036	-0.1434
	(0.59)	(0.94)	(0.80)
Price of other seed	0.0103*	0.0005	0.1235**
	(1.87)	(0.54)	(2.38)
Daily wage rate for farm labor	-0.0131**	-0.0000	-0.2560***
	(2.26)	(0.01)	(3.66)
Price of maize (s-1)	-0.1708**	-0.0269	1.6433**
	(2.27)	(1.63)	(2.06)
Presence of major cash crop	1.0338*	0.3361***	17.1392***
	(1.81)	(3.62)	(3.39)
Agricultural cash income (s-1)	0.0166***	0.0030***	0.0061
	(3.82)	(4.13)	(0.22)
Informal/business income(s-1)	-0.0050	-0.0009	-0.0235
	(0.74)	(0.81)	(0.41)
Salaried/pension income (s-1)	0.0638***	0.0128***	0.6999***
	(2.75)	(2.63)	(2.83)
Remittances (s-1)	-0.0030	-0.0100*	-0.5138*
	(0.22)	(1.71)	(1.79)
distance to fertilizer seller	-0.1287***		-3.5203***
	(3.83)		(4.94)
Main planting season	3.0145***	-0.1120	33.5910***
	(3.52)	(1.41)	(7.06)
Agricultural potential	3.8296***	1.1900***	62.8771***
	(6.64)	(12.11)	(12.32)
Long-term yearly average rainfall	0.0004	0.0001	-0.0198*
	(0.30)	(0.58)	(1.85)
Age of head	-0.0308**	-0.0174***	-0.4620***
	(2.41)	(7.29)	(3.33)
Male head of household	1.2094***	0.0698	4.0637
	(2.91)	(0.80)	(0.86)
Number of adult members	-0.0120	0.0323**	0.9351
	(0.19)	(2.31)	(1.23)
Primary education	0.0254	-0.0710	5.1122
	(0.06)	(0.98)	(1.30)
Group membership	1.2774***	0.3111***	19.7213***
	(3.10)	(2.94)	(3.44)
2004 period dummy	0.1497	-0.4457***	10.5744*
	(0.30)	(2.99)	(1.67)
salary*primary	-0.0143	-0.0049**	-0.1701
	(1.10)	(2.50)	(1.57)
salary*agric potential	-0.0041	-0.0051***	-0.0186
	(0.49)	(2.69)	(0.20)
salary*group membership	-0.0511**	-0.0048	-0.5970**
	(2.42)	(0.97)	(2.53)
Constant	6.4953	5.1394***	3.9669***
	(1.51)	(5.94)	(135.23)
Observations	1832		1832

Absolute z statistics in parentheses; * significant at 10%; ** significant at 5%; *** significant at 1%

Source: Author’s study

Table 8: Double Hurdle and Tobit Estimates for Hybrid Seed (Disaggregated Off-farm)

	Double Hurdle		
	Adoption	Intensity	Tobit
Price of fertilizer	-0.1408***	-0.0491***	-0.1776
	(4.53)	(4.36)	(1.63)
Price of hybrid seed	0.0034	0.0017	0.0144
	(0.47)	(0.54)	(0.41)
Price of other seed	0.0095***	0.0028*	0.0050
	(2.62)	(1.80)	(0.44)
Daily wage rate for farm labor	-0.0024	-0.0016	-0.0340**
	(0.73)	(1.06)	(2.51)
Price of maize (s-1)	0.1202***	0.0099	0.4797***
	(3.12)	(0.59)	(3.20)
Presence of major cash crop	0.5035	0.0726	4.1290***
	(1.52)	(0.67)	(4.14)
Agricultural cash income (s-1)	0.0054***	0.0005	0.0028
	(2.65)	(0.70)	(0.58)
Informal/business income(s-1)	-0.0037	-0.0028**	-0.0139
	(1.37)	(2.29)	(1.29)
Salaried/pension income (s-1)	0.0009	-0.0005	-0.0162
	(0.07)	(0.08)	(0.27)
Remittances (s-1)	0.0006	0.0063	-0.0151
	(0.05)	(1.03)	(0.29)
distance to hybrid seed seller	-0.0755***		-0.2676***
	(3.15)		(2.58)
Main planting season	1.4204***	-0.2514***	7.5574***
	(3.96)	(3.06)	(8.32)
Agricultural potential	2.0666***	0.5615***	10.1022***
	(8.30)	(5.71)	(10.47)
Long-term yearly average rainfall	0.0007	-0.0003	0.0005
	(1.06)	(1.50)	(0.26)
Age of head	-0.0082	-0.0048	-0.0678**
	(1.16)	(1.61)	(2.55)
Male head of household	0.5300**	0.2332**	1.9080**
	(2.35)	(2.48)	(2.05)
Number of adult members	0.0168	0.0215	0.1534
	(0.44)	(1.42)	(1.04)
Primary education	-0.2785	-0.0420	-0.6595
	(1.34)	(0.53)	(0.87)
Group membership	0.7068***	0.1885*	3.2572***
	(2.86)	(1.71)	(2.98)
2004 period dummy	-1.7974***	-0.8529***	-2.0208
	(5.17)	(6.25)	(1.63)
salary*primary	0.0039	-0.0020	0.0091
	(0.66)	(1.11)	(0.40)
salary*agric potential	0.0072	0.0028	0.0187
	(1.52)	(1.29)	(0.89)
salary*group membership	-0.0101	-0.0018	-0.0176
	(0.93)	(0.30)	(0.30)
Constant	1.2008	3.5935***	-14.7538*
	(0.59)	(4.78)	(1.90)
Observations	1832		1832

Absolute z statistics in parentheses; * significant at 10%; ** significant at 5%; *** significant at 1%

Source: Author's study

For the fertilizer demand models, we find that salaried work and pensions drive the positive impact of off-farm income on both adoption and intensity of use: informal business income is insignificant with small coefficients. This result is consistent with our conceptual model and mirrors the bivariate result from Table 2, which showed that households with salaried wage and pension income were more likely to use both inputs, while those with the other off-farm activity types were less likely to do so. The combined effects show similar patterns as with the aggregated model. For hybrid seed, all three off-farm work types have insignificant coefficients in the adoption models. The negative and significant impact of informal business on the intensity model is consistent with our expectations: use of both fertilizer and hybrid seed increases the risk of farm earnings, which, coupled with the high correlation with informal earnings, may reduce input use.

The results from this study indicate that previously received remittance income has no bearing on input adoption decisions. Conditional on using fertilizer, households with higher remittance income tend to use less. This result may seem to deviate from that by Collier and Lal (1984) as discussed earlier. However, the kind of remittance in Collier and Lal (1984) came strictly from wage employment and thus could be more regular and stable. In our case, given that we have no information on the remitter and the kind of activities they engage in, it is not possible to draw firm conclusions from this result.

The fact that salary and pension income is positive and significant on fertilizer adoption and intensity but insignificant on both adoption and amount of hybrid seed used suggests that these households are using some of their off-farm earnings to purchase fertilizer, but they are not making the additional investment of money, time, and knowledge to adopt the hybrid seed/fertilizer *package*. As with the aggregated off-farm models, the impact of salaried income on input intensification is greater for households with no group membership and thus limited access to credit. This result is again consistent with arguments by Collier and Lal (1984) that urban wage employment is an important means of breaking both the credit and risk constraints upon agricultural income.

6.0 Summary and Conclusions

The results from the study suggest differences in the impacts of off-farm earnings on input use and intensification across different inputs and off-farm activity types. The emerging picture is that, holding prices, other incomes, locational and relevant household characteristics constant, previous off-farm earnings have a positive impact on fertilizer use for maize producing households in Kenya. This impact is greatest for households without any group membership thus indicating the importance of off-farm work in relieving cash constraints for those households who have no access to other forms of credit.

The impact on hybrid seed is however insignificant, suggesting that even though households with high off-farm earnings tend to use more fertilizer for their maize, using hybrid seed (plus fertilizer) may imply deeper crop intensification and orientation in maize, and one possibly not attractive to those with higher earnings from off-farm work. Off-farm earnings can thus be used to relax the cash constraint on farming, but only up to some point, beyond which such households appear likely to shift their resources to other uses perhaps with higher returns than agriculture.

Further, the presence of a regular source of earnings in form of a salary or pension seems to be the driving force behind any reinvestment behavior that does occur, as originally hypothesized. This is consistent with our conceptual model, given that salaried wages and pension are relatively stable and have low correlation with farming compared to informal business and remittance income. Again, just as with overall off-farm work, households with salaried income may find it optimal to invest some of their earnings to intensify their maize production, but may not be willing to go all the way at which point the two activities act as competitors for the available labor and capital resources.

The above results for off-farm income are in stark contrast to the effects of agricultural cash income which is positive and significant in all regressions except for the level of hybrid seed use, an exception which is not surprising given discussions earlier in the paper. Controlling for all cash income, the growing of a cash crop seems to positively affect maize intensification. This is consistent with substantial other empirical evidence regarding the spillover effects of cash cropping on food crop production. 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 paper provides empirical evidence of the importance of certain types of off-farm work in relaxing the credit- and risk constraints that typically limit agricultural intensification in Kenya. As regards policy, a multifaceted approach that considers other contraints to intensification, especially in regards to technology generation, returns to input use, input delivery systems and effectiveness of extension, must be considered in drawing policy recommendations.

Given the results of this study, further research on other major crops may help in generating clear patterns, and hence conclusions. Additional important questions for research would be whether off-farm earnings are reinvested in agriculture through purchase of farm capital, commercialization or other non-income generating activities e.g. education, health which too may have an impact on farming and off-farm activities but in the long-run. Further, it would also be important to understand how the household member earning the income affects its reinvestment into agriculture.

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Appendices

Table A1: Mean Off-farm Shares by Region and Agricultural Zone

Region/Zone	% of households with Off-farm work	Means shares of off-farm in total income (%)
Region		
Eastern Lowlands	88	52
Western Lowlands	78	49
Western Transitional	72	34
Western Highlands	74	36
Central Highlands	73	34
Agricultural Zone		
Low	80	46
High	72	35
Total	76	40

Source: Author's calculation

Table A2: Likelihood Ratio (LR) Test for the Tobit Formulation Hypothesis

Model	LR value	P-value
Models I (Aggregated Off-farm)		
Fertilizer	231.12	0.0000
Hybrid Seed	-131.30	1.0000
Models II (Disaggregated Off-farm)		
Fertilizer	236.79	0.0000
Hybrid Seed	-124.52	1.0000

Source: Author's calculation

Table A3: Likelihood Ratio (LR) Test for Joint Vs Separate Estimation

Model	LR value	P-value
Models I (Aggregated Off-farm)		
Fertilizer	53.76	0.0000
Hybrid Seed	223.54	0.0000
Models II (Disaggregated Off-farm)		
Fertilizer	48.89	0.0000
Hybrid Seed	215.75	0.0000

Source: Author's calculation

Table A4: Fertilizer and Hybrid Seed Use by "users" and "non-users" of each Input

Year	Fertilizer	% of households	% using hybrid seed	Mean hybrid seed use/acre	Value of hybrid seed use/acre (Ksh)	Hybrid Seed	% of households	% using fertilizer	Mean fert use/acre	Value of fertilizer use/acre (Ksh)
2000	Non-users	.67	.13	6.79 (5.77)	713 (580)	Non-users	.65	.11	21.52 (33.80)	616 (947
	Users	.33	.79	9.15 (8.88)	954 (923)	Users	.35	.74	42.65 (40.25)	1288 (1560)
	Total		.35	8.55 (8.26)	892 (854)	Total		.33	38.20 (39.86)	1146 (1476)
2004	Non-users	.60	.07	6.63 (5.44)	881 (681)	Non-users	.72	.23	26.80 (31.53)	785 (872)
	Users	.40	.59	6.78 (5.17)	924 (722)	Users	.28	.85	50.82 (50.35)	1665 (2827)
	Total		.28	6.76 (5.20)	917 (715)	Total		.40	40.95 (45.1)	1303 (2280)
Whole sample	Non-users	.64	.10	6.74 (5.64)	769 (618)	Non-users	.69	.17	25.2 (32.2)	735 (896)
	Users	.36	.68	8.02 (7.43)	939 (832)	Users	.31	.79	46.6 (45.5)	1469 (2264)
	Total		.31	7.75 (7.10)	903 (794)	Total		.36	39.7 (42.8)	1233 (1962)

Source: Author's calculation; N/B: Figures represent input use among those households using and those in parenthesis are the respective standard deviations

Table A5: Probit Model Results for the Combined Fertilizer and Hybrid Seed Use

Variable	Estimate	Std Error
Price of Fertilizer	-.0082	.0136
Price of Hybrid	-.0022	.0044
Price of other seed	.0005	.0014
Price of Maize	.0563***	.0193
Cash crop	.1265	.0938
Cash Income	.0009*	.0005
Off-farm Income	.0036	.0046
Mean Distance (input seller)	-.0683***	.0118
Season/Region	1.0301***	.1142
Agric Potential	1.4409***	.1246
Primary education	.1000	.0987
Age of head	-.0086***	.0031
Gender of head	.1485	.1146
Group membership	.5551***	.1618
Period dummy	.1458	.1538
Interactions		
Off-farm*primary	.0023	.0018
Off-farm*Agric Potent	.0014	.0019
Off-farm*Group	-.0065	.0045
Constant	-2.204***	.9030

Note: *** significance at 1% ** significance at 5% and * significance at 10% Note: *** significance at 1%

Source: Author's study

Table A6: Wald Test for the Combined Effects in the Fertilizer and Hybrid Seed Models (Disaggregated Off-farm)

	Adoption Model			Level Model		
Variable	Combined Effect	Wald Stat	p-value	Combined Effect	Wald Stat	p-value
Fertilizer Models						
Primary education	-.1464	.00	.9780	-.1299	1.35	.2461
Agric potential	3.7803	44.19	.0000	1.1287	145.50	.0000
Group Member	.6632	9.01	.0027	.2534	5.85	.0156
Hybrid Seed Models						
Primary education	-.2316	1.77	.1834	-.0660	.23	.6327
Agric potential	2.1531	69.85	.0000	0.5952	33.37	.0000
Group Member	.5854	8.21	.0042	.1669	2.61	.1061

Source: Author's study