EX-ANTE EVALUATION OF CASSAVA RESEARCH FOR DEVELOPMENT IN MALAWI: A FARM HOUSEHOLD AND RANDOM UTILITY MODELING APPROACH

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Contributed Paper presented at the Joint 3rd African Association of Agricultural Economists (AAAE) and 48th Agricultural Economists Association of South Africa (AEASA) Conference, Cape Town, South Africa, September 19-23, 2010.

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Abstract

Ex ante evaluation of agricultural research for development projects has become important in recent years for priority setting, ex post impact assessment and learning about generalizability to other populations and contexts. We apply farm household and random utility modeling to baseline survey data and evaluate the impact of a cassava research for development project in Malawi prior to its implementation. The project is being implemented to unlock the potential of cassava in response to the global food crisis. We find that a high proportion of farm households are not self-sufficient in food production and can be assisted by increasing the productivity of land and labor in production, processing and marketing of cassava to reduce deficits and increase marketed surplus. The research for development embeds research in an innovation systems network and speeds up exposure, awareness, adoption and diffusion. This increases the likelihood that incremental benefits will be generated and accrue earlier compared to the counterfactual without the project.

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Introduction

Most development researchers and practitioners agree that the sharp rise in international prices for agricultural commodities that emerged in 2003 and peaked in 2008 resulted in a global food crisis. In Malawi the government responded in the short term by banning maize exports; revoking licenses of large scale traders and directing the Agricultural Development and Marketing Corporation (ADMARC) to be the sole buyer and seller of maize; fixing minimum buying and maximum selling prices of maize through ADMARC; increasing strategic grain reserves held by the National Food Reserve Agency (NFRA); intensifying the government voucher-based fertilizer and seed subsidy program; promoting winter maize production through distribution of agricultural inputs for free; and distributing free food aid to vulnerable households. The government responded in the medium to long term by building additional silos to increase capacity and decentralize maize storage; and implementing programs for conservation agriculture, contract farming, risk management instruments such as weather insurance, irrigation and local production and buffer stocks of fertilizers.

There are food policy debates about whether or not these policy interventions work and have desired impact especially on poor households and whether to target urban staples such maize, rice and wheat or rural staples and famine relief food crops such as cassava and sweet potatoes. One view is that targeting the big three cereals - maize, rice and wheat - is a more cost-effective way to increase food supplies from expanded domestic production because these are preferred staples for feeding Africa’s cities and reversing the rising imports of cereal grains; improved proven Green Revolution technologies are available “on the shelf” for disseminating to farmers; sources of supplies of commercial and food aid imports are available in world commodity markets; and the foodstuffs have good storage and low transportation costs (Eicher, 1990; Evenson and Gollin, 2003; InterAcademy Council, 2004; UN Millennium Project, 2005; World Bank, 2007).

The other view is that targeting orphan food staples has higher payoffs especially for poor households because they are produced and consumed by poor households; they are well-suited for production under a wide range of agro-ecological zones; they diversify the staple food supply and moderate food price volatility; they are cheaper sources of calories as population density increases; they grow in marginal conditions and produce break-even yields with little labor and fertilizer; they are harvested as and when needed and reduce storage costs; they are important in regional markets during drought years; and they can be processed into high value urban staple substitutes for imported cereals for reversing the unsustainable western food consumption patterns to which many African countries have become hooked (Eicher, 1990; Falcon and Naylor, 2005).

Policy makers need to make hard decisions about tradeoffs and whether a country needs all programs targeted at big three cereals at the expense of other orphan food staples to combat the food price crisis. These are political economy questions. The questions can only be answered by in-depth context specific research that takes into account local political constraints (Eicher and Rukuni, 2003; Rodrik, 2008). There is increasing interest in development economics in randomized experiments to derive results that are more defensible and convincing to policy makers (Banerjee and Duflo, 2008; Imbens, 2009; Angrist and Pischke, 2010).

To inform policy, IITA and national partners are implementing a cassava research for development project. The project is using field experimentation to evaluate the effects of the research for development approach to improve delivery of research benefits to farmers and have impact on productivity and profitability of production and processing of cassava for home consumption and marketed surplus in order to combat the global food crisis. The experiment in Malawi is a component of a multi-site, multi-country project being implemented in several African countries. The countries are Democratic Republic of Congo, Ghana, Malawi, Mozambique, Nigeria, Sierra Leone, and Tanzania. The multiple sites provide a variety of settings for evaluating which approaches work for whom, when, why, and how; and for extrapolating the results to other contexts.

Ex ante evaluation of agricultural research for development projects has become important in recent years for priority setting, ex post impact assessment and learning about generalizability to other populations and contexts. We apply farm household and random utility modeling to baseline survey data and evaluate the impact of a cassava research for development project in Malawi prior to its implementation. We find that a high proportion of farm households are not self-sufficient in food production and can be assisted by increasing the productivity of land and labor in production, processing and marketing of cassava to reduce deficits and increase marketed surplus.

Conceptual framework

Farm household and random utility models are appropriate for analyzing the impact of the food crisis on smallholder production and consumption of food staples, entry points that can be used to assist households to combat the crisis, households' responses to interventions and likely adoption, diffusion and the impact of alternative interventions within an ex ante framework (Sadoulet and de Janvry, 1995; de Janvry and Sadoulet, 2008a, 2008b; Ligon, 2009).

Following Sadoulet and de Janvry (1995) and Ligon (2009) if perfect markets exist for all products and factors, all products and factors are tradables, there are no transaction costs and the market price is the opportunity cost of any product or factor, the farm household maximizes a joint utility function

$$\max_{c_i, l_i, A, L} U(c_1, c_2, l_1, l_2)$$

where $U(c_1, c_2, l_1, l_2)$ is the objective function with two household members $i = 1,2,$ and (c_i, l_i) consumption-leisure pair for person i. The objective function is assumed to be increasing, concave, and continuously differentiable.

The household maximizes the objective function subject to a budget constraint

$$p(c_1 + c_2) + w(l_1 + l_2) \leq [F(A,L) - rA - wL] + rE^a + w(E_1^L + E_2^L)$$

and non-negativity constraints on consumption, leisure and farm inputs. The feasible set depends on

(1) Total household land endowment pooled among household members: E^A
(2) Total time available to each household member: $E_i^L, i = 1,2$
(3) Prices for consumption, labor and land: (p,w,r).

The household takes endowments (E^A, E_1^L, E_2^L) and prices (p,w,r) as given. Let $\Gamma(E^A, E_1^L, E_2^L, p, w, r)$ denote the feasible set for the household.

The household model is separable. Households can their problem in separate steps:

(1) Maximize farm profits
(2) Given total income including farm profits choose a consumption-leisure allocation to maximize utility.

This yields demand, input demand output supply functions.

Demands for consumption and leisure depend only on total income and prices. Demands for consumption and leisure do not depend on (E^A, E_1^L, E_2^L) except through their income effects. Demands for consumption and leisure do not depend on production decisions such as the choice of the allocation of land and labor to production (A,L). Operation of the farm does not depend on household characteristics which influence only the objective function. Since other farm-households face the same prices, marginal products of labor and land should be equated across farmers. The impact of the food crisis depends on whether the prices for products, labor and land are a benefit or a cost. This depends on what the household produces; whether it is a net seller of food and/or labor or a net buyer; the food budget share, the elasticity of consumption of food with respect to income (Engel's law) and the prices of food and their link through the Slutsky equation, and subsistence parameters.

If there are market failures, missing markets, high transaction costs and credit constraints then the household model is no longer separable. The household's production and income problem must be determined simultaneously with its consumption decisions. To characterize the feasible set, assume that there is some randomness to production so that output is given by $F(A,L,\varepsilon)$, where ε is a random variable. Let $\varepsilon \in \Omega$ where Ω has a finite number of elements. The farm household's constraints have to be satisfied for every possible value of ε which may be realized. This gives additional constraints for every possible value of ε. The new feasible set is $\Gamma(E^A, E_1^L, E_2^L, \varepsilon, p, w, r)$. Decisions about how land and time are allocated have to be made before ε is observed. The household's problem is to maximize expected utility

$$\max_{c_i(\varepsilon), l_i, A, L} \sum_{\varepsilon} \Pr(\varepsilon) U(c_1(\varepsilon), c_2(\varepsilon), l_1, l_2)$$

such that

$$p(c_1(\varepsilon) + c_2(\varepsilon)) + w(l_1 + l_2) \leq [F(A,L,\varepsilon) - rA - wL] + rE^a + w(E_1^L + E_2^L)$$

The solution must also satisfy non-negativity constraints on consumption, leisure and farm inputs. Consumption depends on ε. The multiplier $\Pr(\varepsilon)\lambda(\varepsilon)$ is associated with the budget constraints. For the first order conditions for consumption side, consumption and leisure depends on the curvature of the utility function. The first order conditions for the production side cannot be disentangled from the multiplier $\lambda(\varepsilon)$. Consequently the choice of productive inputs will depend on the probability distribution of the marginal utility of income for the household. Farm inputs and consumption demands now become a complicated function of just about everything in the environment. The opportunity cost of consumption for a net seller is the sale price. The opportunity cost of production for a net buyer is the purchase price. An increase in the food price has a positive welfare effect if the household is a net seller of food and a negative effect if it is a net buyer. The effect is proportional to the net sale or purchase of the product.

Because consumption depends on ε, the household's response to rising food prices now depends on increasing productivity of inputs and risk reduction in production for home consumption to meet the food deficits for net buyers of staple foods and substitutability in production and consumption to mitigate negative impacts. Different categories of households are differentially affected according to their net positions on food markets as sellers or buyers, their poverty status and the transmission from international to domestic prices.

Opportunities can be created for households to reduce negative impacts of the food crisis and amplify positive ones through improving access to disease-free planting materials of improved varieties, processing equipment and tools, technical assistance and participation in training programs. The cassava research for development project offers to farm households improved genetic, crop management and processing technologies and marketing and institutional innovations. Households can choose to participate, become aware and adopt the options. The household's decision process is modeled using the random utility framework (Kolady and Lesser, 2005). The household chooses to participate in the market, take-up cassava, become informed of improved cassava production technologies and adopt the crop and practices if the utility with the market participation, cassava take-up and new technologies minus its cost is at least as large as the utility from not participating in the market, not taking up cassava and not adopting improved technologies. This is if:

$$U(1, Y_1 - C; X) \geq U(0, Y_0; X)$$

where 1 indicates market participation, cassava growing and the improved technologies and 0 the alternative. Y_1 and Y_0 are expected returns from market participation, cassava growing and the new technologies and non-market participation, not growing cassava and farmers' current practices; C in the price for market participation and new technology and X is a vector of farm, demographic and contextual characteristics. The farmer's utility function $U(i, Y; X)$ is unknown to the research. The deterministic part of the utility function is $V(i, Y; X)$. The inequality is

$$V(1, Y_1 - C; X) + \upsilon_1 \geq V(0, Y_0; X) + \upsilon_0$$

where υ_1 and are independently and identically distributed random disturbances with zero means and unit variances.

Focusing on the market participation decision making, let Y_1^* denote the latent utility from participating in the market, and Y_2^* denote latent sales. $Y_1 = 0$ is observed because either the household chooses not to participate or the household participate but chooses zero. The two latent variables can parameterized to yield a Tobit or a double hurdle model consisting of a probit and a truncated regression model (Cragg, 1971).

With the implementation of cassava research for development interventions, farmers decide whether or not to adopt agricultural innovations. The framework to model probability of adoption includes dichotomous decisions: grow cassava; learn and become aware of improved cassava technologies; and adopt improved practices. The decision about whether or not to adopt the household adopts innovations in planned for promotion under the cassava project might be correlated with the decision whether or not the household chooses to grow cassava and become aware of new cassava technologies.

Let
$Y_1^* = \beta_1^{'} X_1 + \upsilon_1$
where $\beta_1^{'} X_1 = V(1, Y_1 - C; X) - V(0, Y_0; X) = V^1 - V^0$, $Y_1 = 1$ if $Y_1^* \succ 0$ (grow cassava), and $Y_1 = 0$ otherwise (do not grow cassava). V^1 is the deterministic part of utility from taking up cassava, V^0 is that of not taking up cassava and υ_1 is the disturbance term. Y_1 is the dummy for the household growing cassava and $Y^{*}{}_{1}$ is the underlying latent variable capturing the change in utility from taking up cassava. Let
$Y_2^* = \beta_2^{'} X_2 + \upsilon_2$
where $\beta_2^{'} X_2 = V(Taw, Y_{Taw} - C; X) - V(nTaw, Y_{nTaw}; X) = V^{Taw} - V^{nTaw}$, $Y_2 = 1$ if $Y_2^* \succ 0$ (aware of new technology), and $Y_2 = 0$ otherwise (not aware of new technology). V^{Taw} is the deterministic part of utility from becoming aware of new technology, V^{nTaw} is that from traditional practices and υ_2 is the disturbance term. Y_2 is the dummy for becoming aware of new technology and $Y^{*}{}_{2}$ is the underlying latent variable capturing the change in marginal utility by becoming aware of new technology. Let
$Y_3^* = \beta_3^{'} X_3 + \upsilon_3$
where $\beta_3^{'} X_3 = V(Tad, Y_{Tad} - C; X) - V(nTad, Y_{nTad}; X) = V^{Tad} - V^{nTad}$, $Y_3 = 1$ if $Y_3^* \succ 0$ (adopted improved technology), and $Y_2 = 0$ otherwise (not adopted improved technology). V^{Tad} is the deterministic part of utility from adopting new technology, V^{nTad} is that for current technology and υ_3 is the disturbance term. Y_3 is the dummy for adoption of new technology and $Y^{*}{}_{3}$ is the underlying latent variable capturing the change in marginal utility by adopting new technology.

We assume that $(\upsilon_1, \upsilon_2, \upsilon_3) \sim N(0,0,0,1,1,1,\rho)$ where ρ is the correlation between disturbance terms. This yields a trivariate probit model.

Hypotheses

Applying the conceptual framework generates three hypotheses tested in this study. The first hypothesis is that households not self sufficient in staple food production rely on the market for obtaining access to food and are negatively impacted by the food crisis.

The second hypothesis is that cassava research for development program converts research outputs into desired outcomes through increasing farmers' access to information, disease free planting materials of improved varieties, crop and post-harvest management technologies and markets.

The third hypothesis is that cassava research for development embeds research within an innovation systems network along value chains, speeds up the rate of diffusion and brings forward benefits compared to the counterfactual without the program.

Research design

The project is using a comparison-site multiple treatment design to identify and estimate the treatment effects. This assigns interventions to some geographic areas but not to other areas. Monitoring and evaluation is used to learn which experiments work and which fail by analyzing changes over time of outcomes of sample households in areas in which the project is implemented compared to the counterfactual of no intervention in neighboring non-project areas. The comparison-site design is used because it assigns treatments across geographical areas such as extension planning area and villages and not individual farm households and captures spillovers and externalities benefits that would be underestimated if treatment is only assigned at the individual household level (Miguel and Kremer, 2004).

Rapid rural appraisals and key informant interviews were conducted at the start of the project in January 2009 to collect information and to identify bottlenecks and technological, institutional and policy innovations with a potential to relax the constraints. A national stakeholder meeting was organized to design experiments to discover what works and does not work, select sites and criteria for participation, clarify hypotheses about impact pathways, select key indicators for monitoring and evaluation, develop implementation plans and allocate institutional responsibilities.

The project is being implemented in four districts in the central and northern regions of Malawi: Kasungu, Dowa, Ntchisi, and Mzimba (Figure 1). Districts were selected by stakeholders based on a combination of the following criteria: (a) population of vulnerable households; (b) access to marketing outlets and probability of success; (c) land availability for expansion; (d) presence of processing plants within the districts or surrounding districts; and (e) suitability for growing cassava and preliminary cassava trials conducted and existence of partners (Figure 2). The treatments identified for experimentation and evaluation include working at higher scales and incorporating into research process (on-farm agronomy, crop varieties and integrated soil fertility management) work on rapid multiplication and distribution of disease-free planting materials of recently developed improved varieties; small and medium cassava processing; farmers' organizations and farmer skill development; networking and capacity building among researchers, extension, NGOs; and platforms for integrating different technology, resource management and market interventions to achieve impact at scale.

A total of 16 extension planning areas were purposively selected for field implementation of activities. These EPAs were selected because cassava is an important food staple in production and consumption of households in the areas, there exist cassava processing centers, and public and private sectors partners were available. Five of the 12 EPAs implemented the 1998/1999 to 2000/2001 accelerated multiplication and distribution of cassava and sweet potato planting materials project. Selection of the households for participation in the project was based on willingness of the household to participate in the activities and access to land. The process involved first sensitization of the communities about the project. Farmers that were willing to participate in the project registered and provided estimates of the areas they were planning to crop under cassava. The estimates were aggregated to estimate the total quantities of planting materials that were bulked up and supplied.

Multisite cluster random sampling was used to select focal villages and focal households in target and counterfactual extension planning areas for monitoring and evaluation. All sections within the extension planning areas targeted under the project were first listed. Two sections per each targeted extension planning area were randomly selected. Within selected sections a census of the villages was conducted to develop a village sampling frame. One focal village per section was randomly selected. Within the focal villages households were listed and 16 households per village randomly selected for monitoring and evaluation. The randomly selected households were given preference during the distribution of disease-free planting materials of improved varieties and training programs.

Counterfactual extension planning areas without project interventions that are similar in observable characteristics to the target EPAs were selected. As for the project EPAs, a census of the sections was carried out and one section per EPA randomly selected. Within the selected sections a population list of villages was complied and one village per section randomly selected. For the selected villages, population lists were compiled and 16 focal households per village selected.

The sample size of number of sections per extension planning area, villages per section and households per village was determined to detect an effect of about one standard deviation with a power of 0.80 for the intra-class correlation and conventional confidence intervals subject to the budget constraint. The sample size was determined using the Optimal Design power-analysis software (Spybrook et al., 2009).

Methods

The first hypothesis is tested by developing a household typology based on access to land by farm size and net-buyer net seller dichotomy; identifying entry points and interventions for combating the food crisis; and analyzing household participation in staple food markets and transmission from international to domestic prices. The use of household survey data to implement rural household typologies based on net-buyer net-seller dichotomy is problematic because of the importance of production shocks at the time of the survey (de Janvry and Sadoulet, 2008b). Weather shocks imply that many normally net-seller farm households growing cassava which can stay in the ground for more than one season would be classified among net-buyers because expenditures on inputs are not matched by subsequent output sales in that particular year. de Janvry and Sadoulet (2008b) argue that if the net-buyer net-seller dichotomy is to be used to construct a household typology it should be based not on observed market participation but on predictions from an estimated equation that correlates market participation to a set of household and contextual observable factors. This is the approach followed in this study.

To analyze factors affecting household participation in markets, we fit the Tobit and double hurdle model of Cragg. The Tobit model is appropriate for cases such as household participation in maize and cassava markets in Malawi where the proportions of harvest sold have a limiting value between 0 and 1 and there are many zero observations. The double hurdle model is appropriate for analyzing participation decisions in situations in which the choice involves a first tier of whether or not to choose to participate and a second tier of how much to sell given a decision to sell (Wooldridge, 2002). For the second decision (how much to sell) to come into play, there must be a yes value on the first decision. The Cragg model allows for the differentiation between the influences of a variable on the binary and continuous decisions. The model consists of a probit and a truncated regression model. The dependent variables in the Tobit, probit and truncated models are whether or not the household sells a proportion of its maize and cassava production. The explanatory variables are household head education, cropped area, proportions of the cultivated area planted to maize and cassava, value of farm equipment assets, distance to market, and extension contact. The models are estimated using the tobit, probit and truncreg commands in Stata (StataCorp, 2007).

To estimate the pass-through coefficients of international into domestic prices we follow de Javnry and Sadoulet (2009b). We estimate the relationship

$$p_t^d = \mu + \beta p_t^w + \varepsilon_t$$

where p_t^d and p_t^w are the domestic and international prices of maize at time t and ε_t is white noise. The coefficient β is the pass-through parameter of interest.

The second hypothesis is tested by estimating trivariate probit functions of cassava take-up, awareness and adoption of improved varieties and predicting changes in take-up, awareness and adoption likely to result from cassava project interventions. The multivariate probit model is used because it allows for the simultaneous estimation of a selection equation describing the cassava growing regime into which a household switches, and then regime-specific binary outcome regression models while allowing for correlated unobservables across the three equations. Adoption is measured by whether or not the household grew cassava and used the innovation on its main arable fields during the cropping season. The dependent variables are whether or not the household grows cassava; is aware of the improved variety; and used the improved variety during the 2008/09 cropping season. The same explanatory variables are used in cassava take-up, awareness and variety adoption functions. The explanatory variables are household head education, cropped area, proportions of the cultivated area planted to maize, value of farm equipment assets, distance to market, extension contact, a dummy variable for the household not planting an improved variety during the 2008/09 season because of lack of planting materials, and a dummy variable for de facto female headed household. The functions are estimated using the maximum simulated likelihood estimation in Stata (Cappellani and Jenkins, 2003; 2006). The forecasts are made using mvpredict.

The third hypothesis is tested by analyzing trends in adoption and estimating a duration model for adoption of improved varieties over time for sample households in extension planning areas which implemented the1998/1999 to 2000/2001 accelerated multiplication and distribution of cassava and sweet potato planting materials project compared to those that did not implement the interventions. The rate of diffusion is measured by changes in the percentage of farmers that adopts new innovations over time. Following Fuglie and Kascak (2001) the survival function measures the proportion of the sample that has not yet adopted the technology for each period t. The hazard rate measures the proportion of adopters during period t who have not yet adopted at the beginning of the period. In the baseline survey, farmers were asked to recall the years they had been farming, whether or not they were aware of the existence of a given technology, if they had ever had ever used the technology, when they first used the technology, and if they used the technology during the 2008/09 cropping season. The number of years a farmer has been farming is the analysis time variable, that is, the duration of the process. Adoption of a technology represents the “failure” variable with values of 1 if the farmer has adopted and 0 if the farmer has not adopted. The explanatory variables are household head education, cropped area, extension contact, a dummy for male-headed households with more than one wife, a dummy for de facto female-headed household, a dummy for de jure female-headed household and a dummy variable for living in an extension planning area that implemented the accelerated multiplication and distribution of cassava and sweet potato planting materials project. The function is estimated using -streg- command with the Weibull model with gamma frailty in Stata ((StataCorp, 2007).

Data

Baseline data were collected by interviewing households using a structured questionnaire. The questionnaire was designed to collect data on household, farm and contextual characteristics; crop production and marketing; and technology uptake and adoption trends. The sample was randomly drawn from list frames of farmers in 12 of the 16 extension planning areas targeted under the project and 10 neighboring non-project areas with similar characteristics to the project areas. Households were selected for interviewing using cluster sampling. The sample included 528 households consisting of 375 households drawn from areas targeted under the project and 153 farmers from non-project areas.

Secondary data on cassava fresh roots and maize grain prices in open markets in urban areas and rural centers were obtained from the Ministry of Agriculture and Food Security. Consumer price indices, exchange rates and international maize grain prices (corn U.S. No. 2 Yellow, FOB Gulf of Mexico, U.S. price, U.S. dollars per metric ton) were collected from the International Finance Statistics of the IMF and the National Statistical office of Malawi. Following de Janvry and Sadoulet (2009a, 2009b), domestic prices are deflated using the consumer price index. International prices are transformed in local currency and deflated using the consumer price index.

Results and discussion

Household typology, market participation and price transmission

The social poverty map of sample households shows considerable heterogeneity (Table 1). The production of staple foods is dominated by maize and cassava, especially for sub-family farms with farm sizes ranging from 0.1-1 hectares. Maize accounts for 90 percent the total planted area for marginal farms. The ratio of production that is domestically used for food rather than sold indicates that there is a strong link between production and home consumption. Sample households consume almost all their production, ranging for maize from 97 % for marginal farmers to 93 % for large farmers. For cassava, marginal farmers consume 96% while large farmers consume around 90% of their production. About 83 % of households reported that their major objective growing maize is subsistence while less 31 % of cassava growing households explained that their major objective is for subsistence and the remaining 69 % produce for both food and cash. Surprisingly as high as 62 percent of sample households fail to produce sufficient staple foods to meet their requirements for the year, 52 % buy food and 56 % exchange casual labor for food to make up for deficits in production. Proportionately more marginal farmers are food deficit and depend on the market and hiring out casual labor. Sub-family farms have lower levels of household head formal education, smaller family sizes, fewer members working on household land, and lower levels of investments in farm equipment and livestock assets. They make fewer contacts with extension agents. There are statistically significant differences between UPOCA and comparison extension planning areas in proportion of household land planted to cassava, households growing cassava, and proportion of cassava harvest that is sold. This suggests selection bias resulting from inclusion of extension planning areas that have previously implemented research for development programs. Ex post impact assessment will need to control for this selection bias using estimation methods developed in the literature on micro-econometric evaluation of programs. The methods include propensity score matching, instrumental variables, control function, and difference-in-differences.

The household typology based on farm size and net-buyer net-seller dichotomy has a gender dimension (Table 2). Proportionately more *de jure* female-headed households operate small sub-family farms, fail to produce sufficient food and make up for deficits by buying food and casual labor. De jure female-headed households have older, more experienced and less educated heads compared to other categories. De jure female-headed households have smaller family sizes, labor and farm equipment investments. By contrast de facto female-headed households have the highest investments in farm equipment and are most food self-sufficient because of their greater access to off-farm cash incomes. Proportionately more de jure and de facto female-headed households have ever grown cassava. This shows the greater relative importance of this crop to female headed households.

The map also shows that although all farm categories will be negatively affected by a rise in the price of staple foods, the sub-family farms especially de jure female-headed households will be more negatively affected because of their greater production deficits and reliance on markets and agricultural labor for food. A large majority of the farm households depend on production of maize for home consumption and cassava for both home consumption and sale of surpluses. Therefore the majority can be assisted by increasing the productivity of land and labor in production, processing and marketing to reduce the deficit in food production relative to household consumption.

Table 3 reports the results of the Tobit, probit and the truncated regression model estimates for household participation in maize markets. The statistically significant variables in explaining participation are household head education, value of farm equipment, and extension contact. We test the assumption implicit in the Tobit model that the determinants of censoring are the same as the determinants of the outcome in the uncensored region by comparing the Cragg model with the Tobit by calculating a likelihood ratio test. The test statistic strongly fails to reject the null of the Tobit model. For household participation in maize markets, investment in education, farm equipment and extension are important variables.

Table 4 reports the results of the Tobit, probit and the truncated regression model estimates for household participation in cassava markets. The statistically significant variables explaining participation are different from those for maize. They include the proportion of the cultivated area planted to maize and cassava and distance to market. Not surprisingly cassava and maize are substitutes in production and cassava is bulky and perishable and difficult to transport over long distances to markets. Farm gate processing of cassava may help resolve the distance to market constraint. We test the assumption in the Tobit model that the determinants of censoring are the same as the determinants of the outcome in the uncensored region by comparing the Cragg model with the Tobit by calculating a likelihood ratio test. The test statistic strongly rejects the null of the Tobit model.

Figure 3 summarizes the evolution of international maize grain prices and open market prices of cassava fresh root and maize grain in Mzuzu, an urban consumer market supplied from Mzimba district being targeted under UPOCA. Domestic prices of maize and cassava vary seasonally. Because of different production and harvesting periods, prices of maize reach a peak when cassava prices are low and cassava prices are high when maize prices are low. During drought years maize prices sharply increase but cassava prices remain stable and help moderate rising maize prices. Both international maize and cassava prices sharply increased over the 2006 to 2008 period. But the transmission from international to domestic maize prices appears weak.

To formally test for transmission we test for stationarity and Granger causality. The Augmented Dickey-Fuller and Phillips-Perron unit root test statistics reject the presence of a unit root in both the levels and first differences with non-trended and trended models for the natural logarithm of domestic cassava fresh root and maize grain prices at the 5 percent significance levels (Tables 5 and 6). However, we were unable to reject the null hypothesis of a unit root for the log of international maize grain prices in both levels and first differences at the 5 percent significance levels.

Granger causality tests reject the null hypotheses that the log of Mzuzu maize price does not Granger cause the log of Mzuzu cassava price and the log of Mzuzu cassava price does not Granger cause the log of Mzuzu maize price at the 5 percent level of significance (Table 7). However, we fail to reject the null hypotheses that the log of international maize price does not Granger cause the log of Mzuzu maize price or the log of Mzuzu cassava price and vice versa. We conclude show that cassava fresh root prices Granger cause local maize grain prices and local maize grain prices Granger cause cassava fresh root prices. We concluded that the price transmission from international to domestic prices is weak. This is not surprising because Malawi had maize production surpluses for five consecutive production seasons: 2005/2006, 2006/2007, 2007/2008, 2008/2009 and 2009/2010.

Awareness, adoption and diffusion of improved cassava technologies

The survey revealed widespread awareness and knowledge by farmers of improved cassava varieties and crop management technologies (Table 8). Few farmers were using these technologies primarily due to lack of planting materials constraints. There was very little awareness and knowledge of improved processing technologies.

Table 9 reports the results of trivariate probit model estimates for take-up of cassava and awareness and adoption of improved varieties. The statistically significant variables in explaining uptake of cassava are proportion cropped to maize, value of farm equipment and dummy variable for lack of planting materials. The statistically significant variables in explaining awareness and adoption of improved varieties are proportion under maize, extension and the dummy variable for lack of planting materials. The correlation coefficient between the error terms of the three probits is statistically different from zero. Therefore the equations must be estimated simultaneously. Investment in extension and supply of disease free planting materials of improved varieties is important for increasing the level of area cropped to cassava, awareness and adoption of new technologies. We use the prediction program –mvpred- after –mvprobit- to derive the probabilities of all successes, i.e., probability (grow cassava=1, aware=1, adopt=1) and all failures. i.e., probability (grow cassava=0, aware=0, adopt=0). The mean prediction for all successes is 0.15 and all failures is 0.13. This shows that the cassava project interventions will likely increase cassava growing and awareness and adoption of improved varieties and result in large incremental benefits.

Diffusion and farm level impact

The diffusion of improved varieties and crop management practices over time among sample farmers is shown in Figure 4. Diffusion follows the S-shaped curve although it has still not reached the inflection point. Diffusion follows a stepwise pattern: variety, seed selection, spacing and weeding are simultaneously adopted first, followed by planting time and then by pest and diseases control. Although the earliest adoption of improved varieties occurred in the 1950s, diffusion was very low until the mid-1990s. Variety, seed selection, spacing and weeding technologies have diffused more rapidly in the last 15 years.

The duration patterns show that the fraction of observations with adoption (failure) is 0.19. The 25th, 50th and 75th percentiles of the survival time distribution are 32, 67, and 69 years respectively. Thus it will take about 70 years for 75 % adoption levels at current diffusion rates. The graph of the survivor function shows that households adopt faster in areas that implemented the1998/1999 to 2000/2001 accelerated multiplication and distribution of cassava and sweet potato planting materials project compared to households in areas that did not implement the interventions (Figure 5). The log-rank test of the null of equal survivor functions has a p-value equal to 0.0000, indicating that the survivor functions are unequal. We conclude that exposure to research for development interventions speeds up diffusion compared to without research for development projects.

Table 10 presents the results of estimation of the duration model for diffusion of improved varieties. The tests of the nulls of no difference in hazard rates by household type and area that implemented the accelerated multiplication and distribution of cassava and sweet potato planting materials project have p-values of 0.0158 and 0.0000 respectively. These results show that there are statistically significant differences between households in extension planning areas with research for development experience and those that did not implement these projects. We conclude that research for development speeds up diffusion and permits households to capture benefits earlier compared to the status without intervention.

Conclusions and implications

In Malawi net food buying households in food deficit areas are experiencing poor access because of inadequate supplies and high prices. This study addressed the problem of evaluating the effects of a cassava research for development interventions in response to the global food price crisis prior to its implementation. The study was carried out to benchmark levels of adoption of innovations targeted under the research, set priorities and guide ex post impact assessment. The paper applies farm and random utility modeling approaches to identify the impact of the global food crisis and entry points that can be used to assist household combat the crisis and evaluate alternative cassava research for development interventions.

The study finds that as high as 62 percent of sample households fail to produce sufficient staple foods to meet their requirements for the year, 52 % buy food and 56 % exchange casual labor for food to make up for deficits in production. Although price transmission from international to domestic prices is weak, domestic prices in food deficit areas are high and the majority can be assisted by “next-harvest” agricultural research for development programs to increase the productivity of land and labor in production, processing and marketing to reduce the deficit in food production relative to household consumption and generate marketable surpluses. The interventions being planned under the cassava research for development have more probabilities of success than failure. The research for development program speeds up diffusion and makes benefits accrue to households earlier compared to the status without intervention.

The major shortcomings of the present study are data limitations especially on yields and on-farm agronomic yield responses. The study extrapolated from the experiences of households in areas that have implemented research for development projects compared to those in areas that did not. This approach is valid if there are no significant general equilibrium effects and spillovers. If there are substantial general equilibrium effects the results are no longer valid and general equilibrium approaches need to be used. Future work is needed to compare the ex ante predictions against realized ex post impacts using hierarchical multi-level modeling approaches to improve research prioritization and learning over time.

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Table 1: Household typology by farm size for the project target and counterfactual EPAs, Malawi, 2009

	Farm size (Ha)						non-Project	Project	All	Significance
	0.01-1	1.01-2	2.01-3	>3	All	Significance				
Households (number)	76	200	124	128	528		153	375	528	
Households (%)	14.4	37.9	23.5	24.2	100.0		29	71	100	
Proportion household land allocated to crop										
Maize	0.87	0.57	0.42	0.27	0.51	0.000	0.48	0.51	0.5	n.s.
Cassava	0.03	0.04	0.04	0.03	0.04	n.s.	0.17	0.043	0.035	0.004
Growing cassava: Yes (%)	13.2	15.5	25.8	27.3	20.5	0.010	11.1	24.3	20.5	0.000
Proportion harvest sold										
Maize	3.3	4.5	5.0	7.0	5.0	n.s.	5.9	4.69	5.04	n.s.
Cassava	4.4	5.8	10.6	11.4	8.1	0.024	3.5	9.9	8.1	0.002
Major objective growing maize: Household food only (%)	73.2	85.5	88.3	81.8	83.3	n.s.	87.6	81.7	83.3	n.s.
Major objective growing cassava: Household food only (%)	30.0	23.3	50.0	30.8	31.2	n.s.	42.9	28.4	31.2	n.s.
Household produces enough food: Yes (%)	23.7	32.5	38.7	56.3	38.4	0.000	39.2	38.1	38.4	n.s.
Household buys food: Yes (%)	55.3	56.0	51.6	43.0	51.7	n.s.	50.3	52.3	51.7	n.s.
Other coping mechanism: Casual labor (%)	69.1	61.7	45.7	47.1	56.8	0.018	53.6	58	56.8	n.s.
Formal education (years)	4.6	5.4	5.9	6.4	5.7	0.030	5.9	5.5	5.7	n.s.
Household size (number)	4.7	4.9	5.4	5.7	5.2	0.004	4.9	5.3	5.2	n.s.
Household member work on farm (number)	2.5	2.6	2.8	3.0	2.7	0.006	2.6	2.8	2.7	n.s.
Value of farm equipment (US$)	47.1	111.4	106.4	223.5	128.1	0.012	126.5	128.7	128.1	n.s.
Value of livestock (US$)	139.3	340.6	581.6	825.1	485.7	0.005	651.2	418.1	485.7	n.s.
Visit extension: Yes(%)	14.5	22.5	23.4	35.9	24.8	0.004	20.3	26.7	24.8	n.s.
Extension visit: Yes (%)	19.7	29.5	28.2	38.3	29.9	0.042	30.7	29.6	29.9	n.s.
Farm size: De jure female-headed (%)	15.8	8.5	12.1	7.8	10.2	n.s.	11.8	9.6	10.2	n.s.

Source: Authors' estimates

Table 2: Household typology by gender for the project target and counterfactual EPAs, Malawi, 2009

	De jure female headed	De facto female headed	Male headed one wife	Male headed, more than one wife	All	Significance
Households (number)	54	8	402	64	528	
Household produces enough food: Yes (%)	22.2	62.5	39.1	40	38.4	0.038
Age of household head (years)	54.2	37	41.6	49.3	43.8	0.000
Formal education (years)	3.3	7.0	6.1	4.6	5.7	0.000
Household size (number)	3.8	4.4	5.1	6.9	5.2	0.000
Household member work on farm (number)	1.9	1.6	2.7	3.4	2.7	0.000
Value of farm equipment (US$)	109.7	552.3	114	179.1	128.1	0.015
Farming experience (years)	32.2	11.9	18.4	25.2	20.6	0.000
Grown cassava: Yes (%)	35.2	50.0	33.3	35.9	34.1	n.s.

Source: Authors’ estimates

Table 3: Tobit, probit and truncated model estimates of household participation in maize markets in Malawi, 2008/2009

Dependent: Household sells maize	Tobit				Probit				Truncated			
Explanatory variable	Coef.	Std. Err.	t	P>|t|	Coef.	Std. Err.	z	P>|z|	Coef.	Std. Err.	z	P>|z|
Education	0.066	0.026	2.52	0.012	0.047	0.184	2.53	0.011	0.0117631	0.0046318	2.54	0.011
cropped area	0.019	0.049	0.39	0.698	0.012	0.035	0.35	0.724	0.0034808	0.0092353	0.38	0.706
proportion maize	0.181	0.315	0.57	0.566	0.131	0.224	0.59	0.558	0.033833	0.0560909	0.6	0.546
proportion cassava	-0.454	1.004	-0.45	0.652	-0.290	0.738	-0.39	0.694	-0.0558389	0.1752537	-0.32	0.75
farm equipment	0.000	0.000	2.08	0.038	0.000	0.000	2.19	0.029	0.0001113	0.000042	2.65	0.008
Market	0.001	0.001	1.02	0.310	0.001	0.001	0.99	0.322	0.0002185	0.0002167	1.01	0.313
Extension	0.378	0.194	1.95	0.051	0.278	0.138	2.02	0.044	0.0760388	0.0363546	2.09	0.036
Constant	-2.074	0.383	-5.42	0.000	-1.488	0.232	-6.42	0.000	0.0350048	0.0568901	0.62	0.538
sigma	1.468								0.3778573			
Number of observations	527				527				527			
Log likelihood	-322.807				-240.167				-234.88379			
LR chi2(2)	19.250				19.960				22.9			
Prob > chi2	0.007				0.006				0.0018			
Pseudo R2	0.029				0.040							

Source: Authors’ estimates

Table 4: Tobit, probit and truncated model estimates of household participation in cassava markets in Malawi, 2008/2009

Dependent: Household sells cassava	Tobit				Probit				Truncated			
Explanatory variable	Coef.	Std. Err.	t	P>|t|	Coef.	Std. Err.	z	P>|z|	Coef.	Std. Err.	z	P>|z|
Education	0.016	0.023	0.70	0.487	0.018	0.025	0.70	0.481	0.002	0.003	0.68	0.495
cropped area	0.009	0.045	0.19	0.848	0.012	0.046	0.25	0.799	0.004	0.006	0.67	0.504
proportion maize	-1.094	0.419	-2.61	0.009	-1.049	0.441	-2.38	0.017	-0.076	0.039	-1.97	0.049
proportion cassava	7.051	0.782	9.01	0.000	8.451	0.761	11.11	0.000	2.259	0.121	18.72	0.000
farm equipment	0.000	0.000	0.19	0.850	0.000	0.000	1.15	0.251	0.000	0.000	0.37	0.711
Market	0.002	0.001	1.87	0.062	0.002	0.001	1.74	0.082	0.000	0.000	1.78	0.075
Extension	0.238	0.173	1.38	0.168	0.240	0.184	1.31	0.191	0.040	0.025	1.62	0.106
Constant	-1.488	0.362	-4.10	0.000	-1.625	0.340	-4.78	0.000	0.034	0.039	0.88	0.381
sigma	1.075											
Number of observations	527				527				527			
Log likelihood	-194.261				-122.857				-38.250			
LR chi2(2)	157.860				174.600				391.260			
Prob > chi2	0.000				0.000				0.000			
Pseudo R2	0.289				0.415							

Source: Authors’ estimates

Table 5: Augmented Dickey-Fuller test for unit root for Mzuzu cassava fresh root and maize grain prices and international maize grain price, Malawi, April 1989 to July 2009

Variable	Levels		First differences	
	Non-trended	Trended	Non-trended	Trended
log Mzuzu cassava price	-4.817[c]	-6.601[c]	-3.926[c]	-5.688[c]
	(0.000)	(0.000)	(0.002)	(0.000)
log Mzuzu maize price	-3.599[c]	-4.776[c]	-3.414[c]	-4.609[c]
	(0.005)	(0.000)	(0.01)	(0.001)
log international maize	-1.854	-1.804	-2.122	-2.156
price	(0.353)	(0.703)	(0.235)	(0.515)

Dickey-Fuller values are Z(t) statistics with MacKinnon approximate p-values for testing the null hypothesis of a unit root given in brackets under the statistic.
(c) indicates rejection of the null hypothesis of a unit root at the 5 % level.

Source: Authors' estimates

Table 6: Phillips-Perron test for unit root for Mzuzu cassava fresh root and maize grain prices and international maize grain price, Malawi, April 1989 to July 2009

Variable	Levels		First differences	
	Non-trended	Trended	Non-trended	Trended
log Mzuzu cassava price	-4.352 ^{c} (0.000)	-6.474 ^{c} (0.000)	-4.586 ^{c} (0.001)	-6.492 ^{c} (0.000)
log Mzuzu maize price	-3.613 ^{c} (0.005)	-4.963 ^{c} (0.002)	-3.566 ^{c} (0.007)	-4.797 ^{c} (0.000)
log international maize price	-2.111 (0.240)	-2.154 (0.515)	-1.965 (0.302)	-1.957 (0.625)

Phillips-Perron values are Z(t) statistics with MacKinnon approximate p-values for testing the null hypothesis of a unit root given in brackets under the statistic.
(c) indicates rejection of the null hypothesis of a unit root at the 5 % level.

Source: Authors' estimates

Table 7: Pairwise Granger causality tests for Mzuzu cassava fresh root and maize grain prices and international maize grain prices, Mzuzu, Malawi, April 1989 to July 2009

Null hypothesis	F-Statistic[a]	p-value	lags
log Mzuzu maize price does not Granger cause log Mzuzu cassava price	4.11	0.044	1
log Mzuzu cassava price does not Granger cause log Mzuzu maize price	9.44	0.002	1
log Mzuzu maize price does not Granger cause log international maize price	0.19	0.659	1
log international maize price does not Granger cause log Mzuzu maize price	0.07	0.792	1
log Mzuzu cassava price does not Granger cause log international maize price	0.63	0.428	1
log international maize price does not Granger cause log Mzuzu cassava price	0.01	0.929	1

a. The Granger causality test is an F-test of the joint significance of the other variables in a regression that includes lags of the dependent variable

Source: Authors' estimates

Table 8: Household typology by awareness and knowledge of improved cassava varieties and crop management technologies, Malawi, 2008/2009

	Farm size (Ha)						non-UPOCA	UPOCA	All	Significance
	0.01-1	1.01-2	2.01-3	>3	All	Significance				
Households (number)	76	200	124	128	528		153	375	528	
Households (%)	14.4	37.9	23.5	24.2	100.0		29	71	100	
Awareness Manyokola: Yes (%)	76.0	87.9	84.7	86.7	85.2	0.091	82.2	86.4	85.2	n.s.
Ever used Manyokola: Yes (%)	21.3	26.6	37.1	37.5	31.0	0.021	22.4	34.8	31.0	0.004
Planted Manyokola 2008/09 season	5.3	15.1	23.4	28.1	18.8	0.002	11.8	21.7	18.8	0.067
Where learn Manyokola: Extension/NGOs (%)	11.3	17.5	19.8	15.4	16.7	n.s.	17.4	16.4	16.7	n.s.
Why not use: Lack of planting materials (%)	38.6	44.6	31.4	33.3	37.9	n.s.	40.8	36.8	37.9	n.s.
Awareness planting time (%)	9.2	18.5	29.0	21.1	20.3	0.007	15.7	22.1	20.3	0.058
Used planting time 2008/09 season	6.6	10.0	16.9	14.8	12.3	n.s.	9.8	13.3	12.3	n.s.
Where learn planting time: Other farmers (%)	9.2	15.0	21.0	16.4	15.9	n.s.	15.7	16	15.9	n.s.

Source: Authors’ estimates

Table 9: Multivariate probit regression model estimates of cassava take-up, awareness and adoption of improved varieties in Malawi, 2008/2009

Dependent variable	Grow cassava				Awareness of improved variety				Adopt improved variety			
Explanatory variable	Coef.	Std. Err.	z	P>|z|	Coef.	Std. Err.	z	P>|z|	Coef.	Std. Err.	z	P>|z|
Education	0.028	0.019843	1.41	0.160	-0.00659	0.020414	-0.32	0.7470	0.0307	0.020	1.51	0.132
cropped area	0.005	0.038754	0.13	0.893	-0.02733	0.039506	-0.69	0.4890	0.0315	0.040	0.78	0.437
proportion maize	-0.549	0.292556	-1.88	0.061	-0.48661	0.235159	-2.07	0.0390	-0.7292	0.324	-2.25	0.024
farm equipment	0.000	0.000147	1.94	0.052	0.000485	0.00035	1.38	0.1660	0.0002	0.000	1.49	0.135
Market	0.001	0.000877	1.60	0.109	0.000223	0.000901	0.25	0.8050	0.0014	0.001	1.56	0.118
Extension	0.176	0.150161	1.17	0.242	0.338359	0.172706	1.96	0.0500	0.3401	0.150	2.27	0.023
dummy why not plant lack of materials	-1.395	0.224181	-6.22	0.000	1.449575	0.266726	5.43	0.0000	-1.9128	0.339	-5.64	0.000
dummy de jure female household	0.821	0.508395	1.62	0.106	3.91525	85.40681	0.05	0.9630	0.5382	0.456	1.18	0.238
Constant	-0.722	0.253282	-2.85	0.004	0.973555	0.245548	3.96	0.0000	-0.8251	0.268	-3.08	0.002
/atrho21	0.567	0.121505	4.66	0.000								
/atrho31	1.568	0.145076	10.81	0.000								
/atrho32	0.643	0.13433	4.79	0.000								
rho21	0.513	0.089551	5.73	0.000								
rho31	0.917	0.023157	39.59	0.000								
rho32	0.567	0.091111	6.23	0.000								
Number of observations	525											
Log likelihood	-487.414											
LR chi2(2)	120.600											
Prob > chi2	0.000											

Likelihood ratio test of rho21 = rho31 = rho32 = 0: chi2(3) = 233.143 Prob > chi2 = 0.0000

Source: Authors’ estimates

Table 10: Duration model estimation results for diffusion of improved varieties, Malawi, 2008/09

Explanatory variable	Hazard Ratio	Std. Err.	z	P>|z|
education	1.147	0.048	3.26	0.001
cropped area	0.948	0.047	-1.07	0.283
extension	1.823	0.444	2.46	0.014
dummy male head more than one wife	0.570	0.209	-1.53	0.125
dummy de facto female household	4.516	3.142	2.17	0.030
dummy de jure female household	0.405	0.174	-2.10	0.035
PastR4D	4.367	1.299	4.96	0.000
ln_p	0.544	0.120	4.52	0.000
ln_the	-0.868	1.375	-0.63	0.528
p	1.724	0.208		
1/p	0.580	0.070		
theta	0.420	0.577		
Number of observations	524			
Log likelihood	-241.439			
LR chi2(2)	93.140			
Prob > chi2	0.000			

Source: Authors’ estimates

Figures

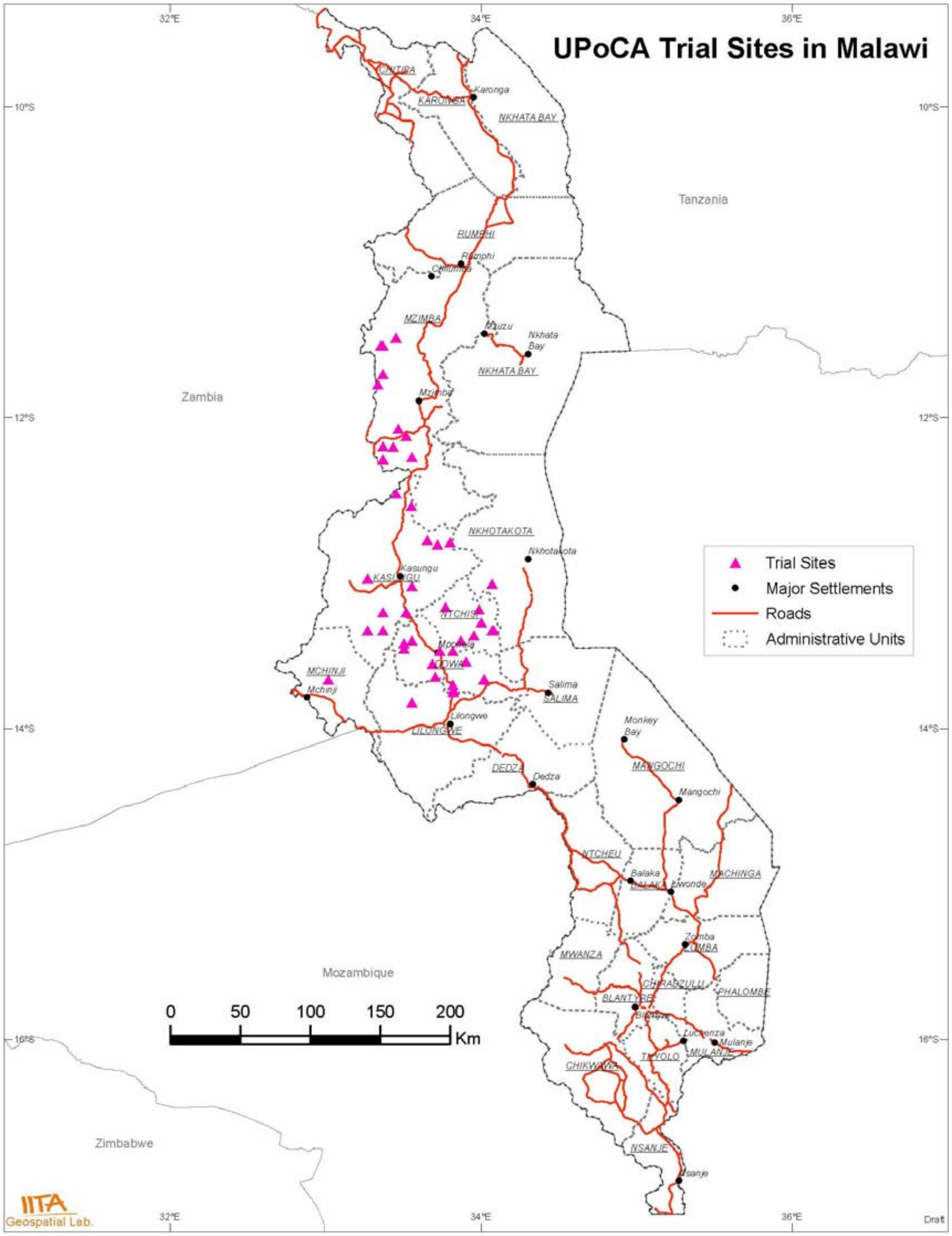

Figure 1: Extension Planning Areas in which cassava research for development project activities are being implemented, Malawi, 2009

Source: Baseline survey, 2009

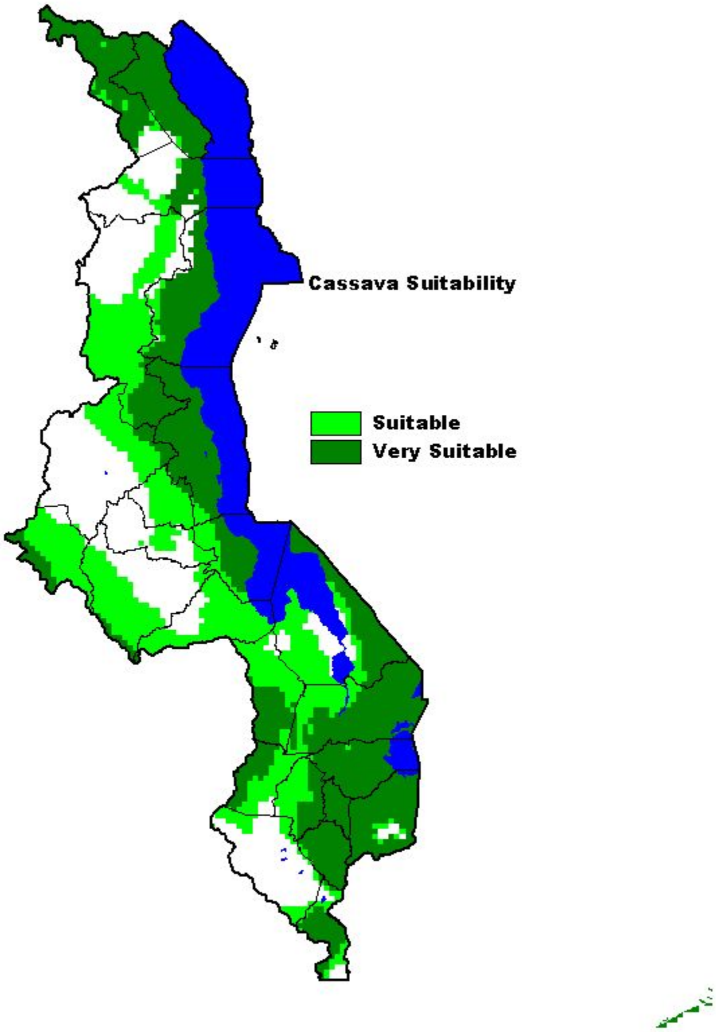

Figure 2: Suitability of extension planning areas for growing cassava

Source: Geospatial Laboratory, IITA

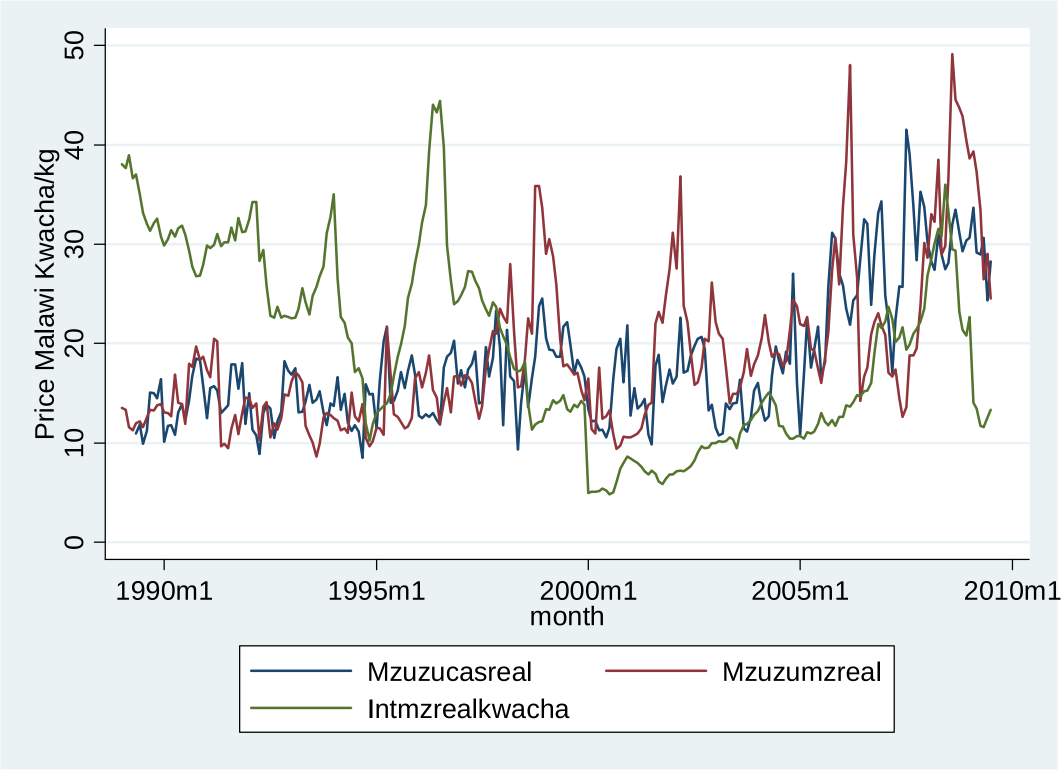

Figure 3: Evolution of international maize grain prices and open market prices of cassava fresh root and maize grain in Mzuzu, Malawi, April 1989-July 2009

Source: Ministry of Agriculture and Food Security, and National Statistical Office, Malawi and International Finance Statistics of the International Monetary Fund

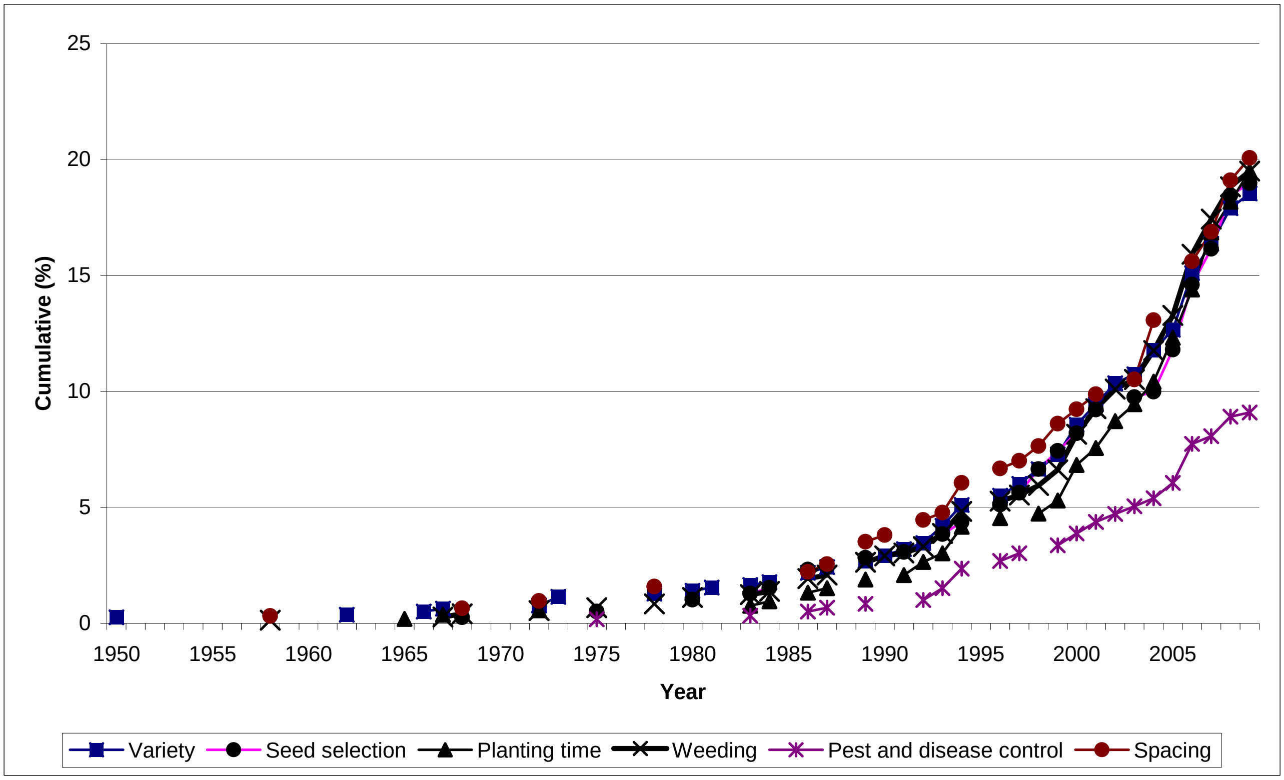

Figure 4: Diffusion of improved varieties and crop management practices over time among sample farmers, Malawi, 2008/09 survey

Source: Authors' estimates

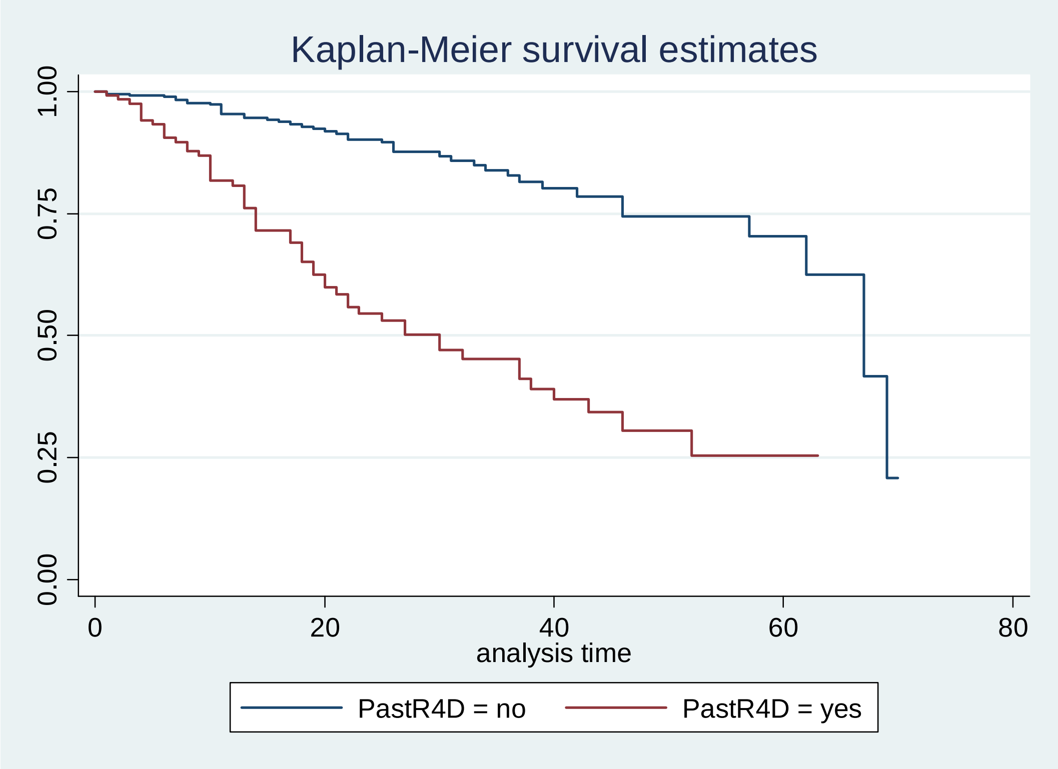

Figure 5: Survivor function of improved variety adoption by households in areas that implemented the accelerated multiplication and distribution of cassava and sweet potato planting materials project compared to households in areas that did not implement the interventions

Sources: Authors' estimates