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Full Length Research Paper

Relevant marginal treatment effects and welfare implications: Lessons from endogenous project interventions in southern Malawi

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This paper evaluates the impact of the Lungwena project using a local instrumental variable framework. It uses participation into a project component as treatment status while non-participation as control. The paper finds that participation into project interventions is positively influenced by household size, entitlement to land and education levels. Sanitation and livestock interventions contributed positively to household welfare.

Key words: Impact, asset index, endogenous interventions.

INTRODUCTION

Progress towards attainment of goals for poverty reduction programs has been registered by both multilateral and bilateral agencies since the early 1990s when World Bank (WB) repositioned itself to embrace the poverty reduction strategies (Moser, 1998). Global priority given to this long-term agenda of poverty reduction took a new turn in the year 2000 at the Millennium Development Summit in New York in United States of America. At this summit, 189 United Nations (UN) member states set eight Millennium Development Goals (MDGs) to be achieved by the year 2015. The focus was on three major areas namely bolstering of human capital, improving infrastructure, and increasing social, economic, and political rights. Much focus was on increasing the basic standards of living. In light of this, eradicating extreme poverty was set as the first goal. Two main targets to achieve this goal were: to halve the proportion of people whose income is less than one dollar a day between 1990 and 2015, and to halve the proportion of people who suffer from hunger during the same period (United Nations Development Programme, 2006).

Based on trends in the last ten years (2002-2012), large reductions in poverty levels (mostly defined in terms of income) have been observed. Rapid and substantial economic growth in the first half of the decade (2000-2010) is reported to have reduced the number of people living on the international poverty line of US$1.25 or less per day from 1.8 billion in 1990 to 1.4 billion in 2005 in the world (Ministry of Development Planning and Cooperation, 2011). While progress is still being made amidst the setbacks of the 2008-2009 food and economic crises, major advances have been reported in China and India, with sub-Saharan Africa still lagging behind. In Sub-Saharan Africa, estimates show that nearly 315 million people were living on the international poverty line of US$1.25 or less per day in the 1990s, with possible rises to almost 404 million by 2015 (Williams, 2005). The escalating poverty is largely attributable to high commodity prices including farm inputs and food prices sparked by the economic downturn, persistent drought, low soil fertility, and the impact of the Human Immune Deficiency Virus (HIV) and the Acquired Immune Deficiency Syndrome (AIDS).

In Sub Saharan Africa, project based interventions to improve standards of living and eradicate extreme poverty have been implemented for decades (Conroy,

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2006). While some projects and programs have been total failures, numerous others have been successful proving that project based approaches to improving standards of living are still important and relevant weapons in the battle against poverty (Kalebe-Nyamongo, 2010).

Project design and selection criteria into treatment play a pivotal role in tracing direct causal effects of interventions to welfare (Ravallion, 2008). Most projects in Sub Saharan Africa have failed to register meaningful impact not necessarily because they were useless or irrelevant but rather they were not well designed and impact could not be well traced. Several methods in econometrics and statistics have been designed to address such problems. Among others, instrumental variables have been used to trace direct causal effects of programs when selection into treatment is endogenous (Angrist and Pischke, 2008). This paper therefore applies a semi-parametric instrumental variables approach (Vytlacil and Heckman, 2007) to measure direct causal effects of an endogenous multidisciplinary project which was conducted in southern Malawi.

The Lungwena health, nutrition and agricultural multidisciplinary project

In support of the country's priorities for the attainment of its Vision 2020 and the MDGs, the University of Malawi and the University of Oslo in Norway have been implementing a multi-disciplinary project to address the problems of poverty, food insecurity and ill-health. With a total life span of nine years from 2004, this South-North partnership project is being financially supported by the Norwegian Government through the Norwegian Fund for Higher Education (NUFU). The implementers include the Malawi government, the people from Lungwena area, and the five constituent colleges of the University of Malawi namely Bunda College of Agriculture, College of Medicine, Kamuzu College of Nursing, Chancellor College and the Malawi Polytechnic (Masangano et al., 2006).

Each college implemented one or more interventions within the catchment area of Lungwena Health Centre in Mangochi District. This is an area which lies on the eastern bank of Lake Malawi and a range of mountains on the eastern side. Lungwena area is about 20 km long and about 5 km wide with an all-weather road passing through. Along this catchment area lies Lungwena Health Centre. The catchment area of the health centre makes a northward stretch on both sides of the road. It is about 33 km away from Mangochi town and 70 km from Chief Makanjira headquarters. The catchment area comprises villages in two Traditional Authorities (TAs) namely Makanjira and Chowe. In 2006, there were a total of 26 villages and 5,174 households in this area (Masangano, 2006 *op. cit.)*.

The key strategies for the project to achieve its set goals and specific objectives include improving agricultural productivity, better nutrition and safety, better and more focused health service delivery, and income generation through enterprise diversification. A baseline survey was conducted in 2002 with a view to identifying issues that affect the welfare of people in the study locations. The study revealed the following. About 18.3% of the total population of about 20,000 people was under-five years, and 49% were below the age of 15 years. This implied that the majority of the population was young and dependent on others. An estimated 18.1% of the households were estimated to be food insecure especially from late October, a period of about four months after the harvest, with the crisis reaching its critical levels (43.1%) between January and March (*ibid)*.

THE MODEL

Tracing and identifying the model for assessing welfare contribution of project interventions is quite difficult because the project was not well designed as it had poorly defined monitoring systems. The approach followed considers that the project was conceived and introduced to people of Lungwena by institutions from outside the system. There were some incentives for people to participate, for example, free livestock, free inputs like seed and san-plat toilets. In addition, selection into project interventions was made by individuals from Lungwena, that is, self-selection. Thus participants were self-selected into the program. It then becomes apparent that the decision to participate into a project intervention was only known by the participating individual but not the institutions introducing the program which only observed the outcome of the decision. This posed the classical problem of selection bias, that is, the participants' characteristics which caused them to select themselves in the project interventions generated unusual or undesirable conditions in the group (Heckman, 1979). In turn, conditions to analyze a variable between participation into program and the outcome (asset based welfare) are causally affected by other endogenous variables in between. This makes impact analysis difficult (Elwert and Winship, 2011).

Against this background, the basic model for selection into the program is adapted from missing information games after Varian (2010) and Salanie (2000). At the beginning of the project, the targeted beneficiaries had *n* project components at their disposal ranging from $a_i, \dots, a_n$. An individual was free to take any of the options given his set of characteristics. Upon choosing a particular option, a range of *m* outcomes denoted as $x_1, \dots, x_m$ were observed. Assuming that an action a_i has been taken by the participant, the implementing agency observes an outcome x_j with a strictly positive probability p_{ij}. The targeted individual received some sort of incentive w_j by participating in a given project intervention. Thus, the participating individuals' von

Neumann-Morgenstern utility function is presented as $u(w)-a$, where *u* is increasing and concave, strictly so. If we assume that the implementing agency is neutral, his von Neumann-Morgenstern utility function becomes $x-w$, that is, the utility accruing to the agency (NUFU and UNIMA) is the difference between the outcomes and incentives given. When the implementing agency brings a project with incentives w_j, the participating individual's utility maximization problem becomes:

$$\max_{i=1,\dots,n}\left(\sum_{j=1}^{m} p_{ij}\, u(w_j)-a_i\right) \quad (1)$$

If the participating individual picks an action a_i amongst the alternatives, then the participation constraint would be:

$$\sum_{j=1}^{m} p_{ij}u(w_j)-a_i \geq \sum_{j=1}^{m} p_{kj}u(w_j)-a_k \quad (2)$$

Where $k=1,\dots n$ and $k\neq i$. This is the incentive compatibility constraint – it says that the utility that the participant gets from choosing to participate in a project sub component must be greater than the utility of any other choice outside the project system. Further, it is assumed that the individual is a rational being as such the utility maximization problem is also subject to a rationality constraint:

$$\sum_{j=1}^{m} p_{ij}u(w_j)-a_i \geq \underline{\mu} \quad (3)$$

Where $\underline{\mu}$ is the utility that the individual obtains from taking an action outside project alternatives. Hence the individual will tend to participate in a project component if the utility obtained from the given subcomponent is at least greater than an outside alternative (Varian, 2010 *op cit*).

Therefore building from the theoretical model, it is first necessary to model the decision to participate into an intervention. After that, it is possible to assess impact of various components of the project and to correct for selection bias resulting from zero participation by using a sample selection framework (Heckman and Vytlacil, 2007). First, it is worth noting that since the impact model requires data for each of the interventions, it is also important to estimate participation equations for those variables. However, it is important to notice that the data for different interventions have been collected from the one individual household at a given point in time. The error terms across the equations of different interventions might be correlated and might further be correlated with unobservable variables since data were collected from the same individual whose decision on a particular intervention may affect the probability of participating in another intervention. This situation therefore calls for a multivariate probit model which can predict jointly the probabilities of participation into project interventions while controlling for the aforementioned problems (Capellari and Jenkins, 2003).

After the decision has been modelled using multivariate probit model, a non-parametric selection model can be used to analyse impact of program participation. Policy Relevant Marginal Treatment Effects (PRMTE) is a local instrumental variable estimation procedure which is similar to a sample selection model but differs in a way because PRMTE uses semi-parametric procedures to calculate marginal treatment effects. Several factors were used to control for treatment effects such as demographic factors, education, institutional and geographic factors (Heckman and Vytlacil, 2001).

In each program component, the potential outcome (for example, asset based welfare) is defined as:

$$Y_1=\mu_1(X)+U_1 \text{ and } Y_0=\mu_0(X)+U_0$$

Where $\mu_1(X)\equiv E(Y_1|X=x)$ and $\mu_0(X)\equiv E(Y_0|X=x)$. Then the benefit to program participation is $Y_1-Y_0=\beta=\mu_1(X)-\mu_0(X)+U_1-U_0$. The average treatment effect conditional on $X=x$ is given by $\bar{\beta}(x)=E(\beta|X=x)=\mu_1(X)-\mu_0(X)$. The average treatment effect on those who chose to participate into the program component conditional on $X=x$ is given by $E(\beta|X=x,S=1)=\bar{\beta}(x)+E(U_1-U_0|S=1,X=x)$. In this case, it is not required that *X* should be independent of (U_0,U_1) in order for the analysis to be identified. The entire analysis therefore conditions on *X* (Heckman and Vytlacil, 2007).

Let I_s be the net impact of program participation which depends on observed variables *(Z)* and unobserved variables *(V)*:

$$I_s=\mu_s(Z)-V$$

$$S=1 \text{ if } I_s\geq 0; S=0 \text{ otherwise}$$

V is assumed to be a continuous random variable with a strictly increasing distribution function F_v. Further, V may depend on U_1 and U_0 in a general way. The *Z* vector may include some or all of the components of *X*, but also includes variables excluded from *X*. Therefore, it is assumed that (U_0, U_1, V) is independent of *Z* given *X*. The additive separability between *Z* and *V* in the latent index plays an essential role in the instrumental variable literature in that it helps with monotonicity among others.

The model, with *Z* independent of (U_0, U_1, V) given *X* is implied by the Imbens-Angrist independence and

Table 1. Variables used to analyze contribution of project interventions to welfare.

Variable		Mean	Std. Err.	[95% Conf.	Interval]
Sanitation	Participation dummy (1 if Yes)	0.571	0.022	0.528	0.614
Crop husbandry	Participation dummy (1 if Yes)	0.377	0.022	0.335	0.420
Livestock husbandry	Participation dummy (1 if Yes)	0.536	0.022	0.492	0.579
Age of the household head	Years	39.287	0.733	37.846	40.727
Gender of the household head	Dummy (1 if female)	0.237	0.019	0.200	0.274
Asset index	Welfare indicator	9.999	0.008	9.984	10.014
Land holding size	Hectares	2.067	0.060	1.949	2.186
Access to agricultural extension	Dummy (1 if yes)	0.619	0.022	0.576	0.661
Access to credit	Dummy (1 if yes)	0.008	0.004	0.000	0.016
Education level of head					
No formal education	Dummy (1 if yes)	0.493	0.024	0.446	0.540
Primary school std 1 – 4	Dummy (1 if yes)	0.260	0.021	0.219	0.302
Primary school std 5 – 8	Dummy (1 if yes)	0.221	0.020	0.182	0.260
Secondary school and above	Dummy (1 if yes)	0.026	0.008	0.011	0.041

monotonicity assumptions (Imbens, 2010). $P(z) \equiv \Pr(S = 1|Z = z) = F_v(\mu_S(z))$, where we keep the conditioning on *X* implicit. $P(z)$ is called the propensity score. Defining $U_S = F_v(V)$. It is uniformly distributed by construction, and different values of U_s correspond to different quantiles of *V*.

Rewriting the selection equation using $F_v(\mu_S(z)) = P(Z)$ so that $S = 1$ and $P(Z) \geq U_S$. $P(Z)$ is the mean scale utility function in discrete choice theory. Then the Marginal Treatment Effect is defined by:

$$MTE(x, u_s) \equiv E(\beta | X = x, U_s = u_s)$$

This is the mean program participation effect for individuals with characteristics $X = x$ and $U_s = u_s$. The MTE uses the method of local instrumental variables in estimation. It is identified by differentiating $E(Y_1 | X = x, P(Z) = p)$ with respect to p which can be computed over the support of the distribution of $P(Z)$ (Heckman and Vytlacil, 2007 *op cit*).

DATA AND VARIABLES USED

A probability proportion to size sampling design was used to collect cross-sectional data from households in the area (World Bank, 2012). The data were collected in Mangochi District which is one of the districts in Southern Malawi. One Traditional Authority (TA), Makanjira in Mangochi district, was purposely chosen since it is where the project was implemented. Villages in Lungwena area were then selected while making sure larger villages were more represented. The sample included 512 households in total. Table 1 presents variables used in the analysis.

RESULTS AND DISCUSSION

The multivariate probit model shown in Appendix A indicated no significant correlations among the program components. This meant that the decision to participate into a project intervention could be modelled using binary response ordinary probit models. Nevertheless, the gains in reduction of effects of unobservable factors still make it useful. When the decision to participate into a project intervention was disaggregated from the multivariate probit by using ordinary probit, several variables became statistically significant.

The decision to participate

Household size drives the decision to participate in livestock and crop husbandry interventions particularly because higher households have more labour and can diversify into other activities which could enhance their livelihoods. Further, larger households face more risks so participation into livestock and crops farming is also a means of shielding themselves against risk. In addition, individuals who went as far as tertiary education were more likely to participate in livestock intervention compared to individuals with lower levels of education. There were geographical differences in participation status with Chapola village indicating statistical significance. This significance is singularly because the village had all interventions present so variability was large in decisions to participate. Individuals with land entitlement for agriculture were more likely to participate

Table 2. Results of the policy relevant marginal treatment effects (PRMTE).

Variable	Sanitation			Livestock			Crop			Total		
Asset index as dependent variable	**Coef.**	**Std. Err.**	**Sig.**	**Coef.**	**Std. Err.**	**Sig.**	**Coef.**	**Std. Err.**	**Sig.**	**Coef.**	**Std. Err.**	**Sig.**
Marginal treatment effects												
Sanitation	0.0613	0.0176	***									
Livestock				0.0388	0.0180	**						
Crop							-0.0163	0.0191				
Participation (Overall)										-0.0306	0.0247	
Demographic factors												
Gender of the household head	-0.0444	0.0405		0.0366	0.0633		0.1186	0.2959		0.0278	0.0634	
Age of the household head	-0.0089	0.0079		0.1533	0.1910		-0.0128	0.0210		0.1281	0.1912	
Age of the household head squared	0.0001	0.0001		-0.0013	0.0017		0.0001	0.0002		-0.0011	0.0017	
Household size	-0.0224	0.0388		0.1459	0.1639		-0.0311	0.0960		0.1244	0.1642	
Education												
No schooling	0.0753	0.2728		2.2285	1.7419		0.3141	0.4422		2.1617	1.7480	
Primary School	0.1379	0.2919		2.3044	1.7861		0.3569	0.4726		2.2264	1.7923	
Secondary School	0.2614	0.4043		2.6278	2.0904		0.3864	0.5795		2.4950	2.0970	
Tertiary education	-0.1231	0.3512		2.9083	2.3223		-0.0386	0.8780		2.7320	2.3290	
Resource factors												
Land holding size	-0.0218	0.0299		-0.0209	0.0303		-0.0216	0.0305		-0.0123	0.0304	
Land holding size squared	0.0053	0.0051		0.0058	0.0052		0.0060	0.0052		0.0046	0.0052	
Institutional factors												
Access to credit	0.6560	0.8758		0.1442	0.3174					0.1090	0.3180	
Access to extension	-0.2599	0.2870		0.8325	1.0274		-0.3928	0.7801		0.7163	1.0292	

in crop intervention and livestock husbandry. This is because land is one of the key factors of production.

Impact of interventions on asset based welfare

Table 2 shows sanitation and livestock components of the program indicating significant positive contributions to household welfare, while the crop husbandry did not register impact. Generally, impact of the entire project was masked by the participation in crop farming since a large proportion of individuals participated in that component of the project. Therefore the PRMTE procedure indicates that some components of the project, that is, sanitation (6% impact) and livestock (4% impact) had an impact on asset-based welfare of individuals in Lungwena.

Conclusions

The analysis finds that in general household, composition

Table 2 Contd.

Geographical location										
Chapola village	0.0910	0.0430		0.0700	0.0434	0.0822	0.0429	*	0.0817	0.0435
Chilonga village	0.0283	0.0539		-0.0023	0.0549	0.0228	0.0545		0.0234	0.0548
Chiponda village	0.0549	0.0452		0.0395	0.0450	0.0468	0.0452		0.0340	0.0456
Kwilasya village	0.0840	0.1073		0.1140	0.1079	0.1172	0.1080		0.0984	0.1087
Mdala Makumba village	0.0753	0.0436	**	0.0708	0.0439	0.0744	0.0438	*	0.0817	0.0443
Milombwa village	0.0439	0.0434		0.0299	0.0438	0.0350	0.0435		0.0383	0.0439
Mizinga village	0.0460	0.0957		0.0154	0.0953	0.0099	0.0953		0.0178	0.0957
Mtumbula village	0.0432	0.0705		0.0541	0.0433	0.0567	0.0429		0.0572	0.0435

Notes: Robust standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1.

in terms of size and the availability/entitlement of land to cultivate plays a central role in determining the decision to participate in a particular intervention. Livestock husbandry practices were mainly adopted by younger individuals who also had access to credit. On the other hand, household composition, availability of land and access to agricultural extension were key factors for participation in crop husbandry practices.

Sanitation and livestock components of the program indicated significant positive contributions to household welfare while the crop husbandry did not register impact. Therefore the PRMTE procedure indicates that some components of the project, that is, sanitation (6% impact) and livestock (4% impact) had an impact on asset-based welfare of individuals in Lungwena.

REFERENCES

Angrist J, Pischke (2008). Mostly Harmless Econometrics: An Empiritist's Companion. London: Massachusetts Institute of Technology.

Capellari L, Jenkins S (2003). Multivariate probit regression using simulated maximum likelihood. The Stata J., 3(3): 278–294.

Conroy A (2006). The History of Development and Crisis in Malawi. In A. M. Blackie, J. Whiteside, Malewezi, & J. S. (eds), Poverty, Aids and Hunger: Breaking the Poverty Trap in Malawi. New York: Palgrave Macmillan.

Elwert, F., & Winship, C. (2011). Endogenous Selection Bias. Boston: Harvard University.

Heckman J (1979). Sample selection bias as a specification error. Econometrica 47. *Econometrica*, pp. 153-161.

Heckman J, Vytlacil E (2001). Policy-Relevant Treatment Effects. Nashville: Americanl Economic Association.

Heckman J, Vytlacil E (2007). Econometric Evaluation of Social Programs, Part I: Causal Models, Structural Models and Econometric Policy Evaluation. In J. Heckman, & E. Leamer, Handbook of Econometrics (pp. 4779-874). Elsevier.

Heckman J, Vytlacil E (2007). Marginal Policy Analysis and Fun with the Borel Paradox. Chicago: Cowles Foundation.

Imbens G (2010). Lectures on Evaluation Methods. Miami: Impact Evaluation Network.

Kalebe-Nyamongo C (2010). Mutual Interdependence between Elites and the Poor. Helsinki: UNU World Institute for Development Economics Research (UNU-WIDER). Working Paper No. 2010/117.

Ravallion M (2008). The Mystery of Vanishing Benefits: An Introduction to Impact Evaluation. The World Bank Econ. Rev., pp. 115-140.

Salanie B (2000). The Economics of Contracts. London: The MIT Press.

The World Bank (2012). Living Standards Measurement Study. Retrieved 06 10, 2013, from Sampling with Probability Proportional to Size: http://go.worldbank.org/QM2VE8B1S0.

Varian H (2010). Intermediate Microeconomics. New York: Norton.

APPENDIX A

Table A1. Results of a multivariate probit model.

Selection model	Sanitation			Crops			Livestock		
	Coef.	Std. Err.	Sig.	Coef.	Std. Err.	Sig.	Coef.	Std. Err.	Sig.
Gender of the household head	-0.012	0.021		-0.012	0.021		-0.012	0.020	
Age of the household head	-0.003	0.004		-0.003	0.004		-0.003	0.004	
Age of the household head squared	0.000	0.000		0.000	0.000		0.000	0.000	
Household size	0.010	0.007		0.010	0.005	**	0.011	0.005	**
Land holding size	-0.016	0.029		-0.016	0.029		-0.016	0.029	
Land holding size squared	0.005	0.005		0.005	0.005		0.005	0.005	
Access to extension	-0.011	0.044		-0.007	0.023		-0.007	0.022	
Access to credit	-0.066	0.165		-0.080	0.106		-0.080	0.103	
Education level									
Junior primary school	0.019	0.021		0.018	0.020		0.019	0.020	
Senior primary school	-0.015	0.039		-0.018	0.022		-0.018	0.022	
Junior secondary school	0.023	0.067		0.027	0.056		0.027	0.055	
Chapola	0.074	0.041	*	0.073	0.042	*	0.073	0.042	*
Chilonga	0.009	0.052		0.009	0.053		0.008	0.053	
Chiponda	0.036	0.044		0.036	0.044		0.036	0.044	
Kwilasya	0.097	0.105		0.097	0.106		0.097	0.106	
MdalaMakumba	0.069	0.042		0.069	0.043		0.069	0.043	
Milombwa	0.034	0.042		0.034	0.043		0.034	0.043	
Mizinga	0.011	0.092		0.010	0.093		0.010	0.093	
Mtumbula	0.052	0.042		0.052	0.042		0.052	0.042	
Constant	9.997	0.255	***	9.973	0.100	***	9.970	0.149	***

Notes: Robust standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1.

Table A2. Results of intervention specific probit models.

Variable	Sanitation			Livestock			Crop		
	Coef.	Std Err.	Sig.	Coef.	Std Err.	Sig.	Coef.	Std Err.	Sig.
Demographic factors									
Gender of the household head	0.031	0.148		-0.265	0.163		0.024	0.152	
Age of the household head	0.006	0.025		0.018	0.027		0.065	0.026	***
Age of the household head squared	0.000	0.000		0.000	0.000		-0.001	0.000	**
Household size	0.035	0.031		0.087	0.033	***	0.056	0.032	
Education									
Primary school	-0.041	0.150		-0.045	0.157		0.032	0.153	
Secondary school	-0.200	0.157		-0.181	0.168		0.175	0.160	
Tertiary education	0.248	0.405		0.955	0.418	***	0.287	0.389	
Factors of production									
Land under agriculture	-0.007	0.217		0.359	0.224	*	0.416	0.228	***
Land squared	0.026	0.037		-0.050	0.038	*	-0.070	0.039	***
Institutional factors									
Access to credit	-0.733	0.770					0.105	0.672	
Access to agricultural extension	0.248	0.128	**	0.706	0.139	***	0.353	0.130	***
Constant	-0.145	0.492		-1.595	0.522	***	-2.019	0.510	***

Notes: Robust standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1.