Access to Productive Assets and Impact on Household Welfare in Rural Uganda

Tilgang til produktive ressurser og virkninger på rurale husholds velferd i Uganda

Philosophiae Doctor (PhD) Thesis

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Introduction

Access to Productive Assets and Impact on Household Welfare in Rural Uganda

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1. Introduction

Improvements in household wealth and welfare play vital roles in sustainable development[1]. Sustainable development occurs when households are able to secure a level of well-being that enables them to cope with and recover from shocks (Rakodi 1999), and does not decline over time (Dixon & Hamilton 1996; Hamilton & Kunte 1997). The recent recommendations from the World Bank emphasize the importance of natural and human resources as key instruments to guide policies for sustainable development (Dixon & Hamilton 1996; Hamilton & Dixon 2003). And whilst sustainable development is expected to enhance basic aspirations of social progress, economic development and ecological integrity (UNDP 2004), the prevailing empirical evidence about the impact of access to the natural and human resources on household welfare in developing countries is to a large extent equivocal and mixed (Appleton et al. 1996; Deininger & Mpuga 2008; Roodman & Morduch 2009). Equitable growth in household access to and investment of savings in natural and human resources can be imperative for sustainable economic growth and poverty reduction.

Research evidence that can underpin reasonable and defendable policy decisions must be seen to be robust, objective, authentic, and easy to interpret. Robust research evidence is expected to have a clear line of argument based on credible analytical methods and should also be: widely applicable in different contexts, reliable in forming a sound basis for evaluation, clean from any residual bias, and able to stimulate action based on different viewpoints that seek to empower and speak to key questions of development (Shaxson 2005; Stock 2010). The phenomenon of anecdotal empirical research evidence may provide insufficient amount of policy relevant information. A mismatch between the expectation of policy makers and actual conditions on the ground can then be created leading to potential controversy and policy failures (Howlett 2009). Arguably, interventions based on the prevailing mixed and less robust evidences may

[1] Sustainable development can be defined as a well-being that does not decline over time (Dixon and Hamilton, 1996), or preserving and enhancing the opportunities that are available to people in countries around the world (Serageldin and Steer, 1994).

fail to generate measurable improvements in the lives of the rural poor. This dissertation provides methodological and policy insights on how investment in productive assets might enhance economic returns and household welfare in rural Uganda. The findings of this thesis are expected to contribute significant evidence for evidence-based policy making and its ancillary strategy of reducing income poverty in Uganda.

Access to assets has long attracted the attention of development practitioners especially in developing countries. It is widely believed that access to productive assets including land, human capital, livestock, and farm equipments may play a significant role in enhancing the welfare of rural households. In particular, insufficient access to land and low productivity of land are considered to be major causes of rural poverty and food insecurity (Melmed-Sanjak & Lastarria-Cornhiel 1998; Holden et al. 2008a). Several recent studies (Riethmuller 2003; Ellis & Freeman 2004; Kristjanson et al. 2004) also show that an increase in access to land and non-land assets, when combined with the diversification of enterprises, can boost incomes of rural households and their abilities to secure better living standards. However, this requires the adoption of policies that enhance asset accumulation and further growth in the productivity and returns to assets. Knowledge of the poverty reduction effects of access to different productive assets is therefore crucial for policy makers to ensure effective prioritization of policy interventions that reduce rural poverty.

Several studies have examined the ability of households to manage risk[2] and smooth consumption in environments that are characterized by incomplete formal financial markets, uninsured risk, ubiquity of credit (borrowing) constraints, and farm household' aversion to risk (Deaton & Muellbauer 1980; Deaton 1990; Deaton 1991; Deaton 1992a; Rosenzweig & Wolpin 1993; Zimmerman & Carter 2003; Kazianga & Udry 2006). A combination of these characteristics not only create fluctuations in income, but may also limit the remunerative use of assets and the ability of households to take on profitable activities (Rosenzweig & Wolpin 1993; Dercon 2002; Dercon 2005). However, access to assets can help rural households to deal with income uncertainty and to move out of poverty.

[2] Risk is a measure of uncertainty and can be measured in form of variance in income, probability of loss, and size of maximum possible loss. Risk and vulnerability can be caused by factors that range from drought, health shocks, pests, commodity price shocks, political strife, conflicts, thefts and many other shocks (Dercon 2005).

Use of livestock as a buffer stock in the wake of covariant shocks such as drought seasons can be a costly strategy to achieve consumption smoothing because livestock are sold at a time when they fetch very low prices (Holden & Shiferaw 2004). There can be considerable indirect effects on household welfare and a response of livestock sales, when the impact of drought on crop and livestock prices exceed the direct production effects. Furthermore, the net-livestock sales may not compensate for losses in income from other sources in risky environments, where common shocks cause death of livestock and a reduction in returns to asset endowments and crop enterprises (Dercon 2002). For example, Kazianga and Udry (2006) estimated the role of livestock in rural Burkina Faso, and found little evidence of consumption smoothing and risk sharing. Households instead relied almost exclusively on self-insurance in the form of adjustment of grain stocks to smooth out consumption. Households are therefore likely to enhance the remunerative use of and investments in additional productive assets that serve as safety nets and sources of higher incomes, when faced with a combination of a stringent liquidity constraint, a strong precautionary savings motive especially at low levels of asset holdings, and the need to maintain a certain level of reproductive assets.

In most African countries, population growth, and customary practices of sub-dividing land among children have created land fragmentation. In Uganda, this has created small farms that obtain higher value of crop production and contribute significantly to serious soil erosion and land degradation, especially in the highlands (Pender et al. 2004a). There is need for effective strategies that can increase; land access, sustainable intesification, agricultural production, food security, family planning, and off-farm income of households. In particular, access to land through market and non-market transfers can reallocate land to land-poor producers, stimulate investment on the land and enhance land productivity by improving the balance of factor ratios. However, efficient land transfers from land-rich to land-poor households can be significantly hampered by the presence of imperfections in the markets for land and credit. Land sales prices become too high and poor households are rationed out of land and credit markets, which further limit better access to land and non-land capital (Melmed-Sanjak & Lastarria-Cornhiel 1998). It is therefore important to verify, in a robust manner, modes of land access that might be effective in increasing rural household welfare.

People tend to invest in non-land assets including in themselves to enhance their welfare, to improve their ability to master technology, and to access a wider range of livelihood choices including access to off-farm earning opportunities (Schultz 1961; Dixon & Hamilton 1996; Le

et al. 2003). However, evidence on the impact of education attainment on rural farm households' productivity and welfare in developing countries, including Uganda, is mixed. Important reasons for this are the estimation challenges related to the endogeneity of education and other asset endowments, the failure to control for the unobserved characteristics of households, data limitations, and the use of weak analytical methods (Appleton & Balihuta 1996; Appleton et al. 1996; Finan et al. 2005; Kurosaki & Khan 2006; Roodman & Morduch 2009).

1.1. The objectives and research questions

The main objectives of this thesis are to:

- Provide robust empirical evidence on the impact of land access through market and non-market avenues on household welfare that is also measured in form of expenditure per adult-equivalent. The research question is whether the welfare effects of land access after controlling for observable and unobservable factors, are significantly different for different modes of land access that include a) inheritance, b) a combination of inheritance and other methods of acquisition, and c) through market access and borrowing.

- Assess the poverty effects of changes in household human capital endowment and idiosyncratic health shocks to human capital that include anticipated and non-anticipated death incidences and sick-days. Here, the research questions are whether changes in human capital have a significant effect on real household consumption expenditure per adult equivalent, and also whether households are able to protect themselves against the health shocks through consumption smoothing.

- Estimate the impact of the number of own and fostered young children (below 10 years) on household welfare in rural Uganda. The research question is to what extent does the variation in the absolute (number) and adult-equivalent of young children, and the likely interaction with adult human capital affect household welfare measured as real household expenditure per adult-equivalent.

- Assess the poverty effects of variation in access to livestock holdings and productive farm equipments. The paper further evaluates the level of the dispersion and the distribution of livestock holdings and farm equipments across households of different levels of expenditure per adult-equivalent. Here, the research questions are; to what extent does the

variation of the endowments of livestock and farm equipments affect household welfare measured as real household expenditure per adult-equivalent. What are the degrees of inequality and statistical differences in the distribution of endowments of livestock and farm equipments across households of different welfare levels in rural Uganda?

- Provide a synthesis of the relative poverty reduction impacts of household access to key productive assets (land operated (acres), adult human capital in Uganda shillings (Ug.shs), livestock endowment (Ug.shs), and physical farm equipments (Ug.shs) using a translog production function. Here, the research questions are whether the marginal effects of each of the productive assets remain significant and robust when evaluated jointly as opposed to the separate assessments, and whether there are significant interactions (synergies) that characterize assets as complements or just as substitutes (facilitate an asset portfolio specialization) in household income generation in rural Uganda.

1.2 The scope

This thesis is grounded in economic theory of production and consumption and utilizes different econometric methods to assess the impact of investment in productive assets on household welfare. Non-experimental econometric methods that exploit the panel nature of data are employed in the analysis of welfare effects of household investments in land, adult human capital, young children, livestock, and productive farm equipments. The analysis did not assess the effects of social capital and financial capital due to data limitations on these two household assets. Quasi-randomization through a variety of econometric methods was utilized to identify the key causal effects of interest and to provide statistical inferences that are robust to the effects of various spurious correlations in the data. These methods can establish causality between access to assets and household poverty levels.

The endowments of productive assets may be endogenous due to selection and unobserved heterogeneity. The endogeneity creates methodological challenges of establishing unbiased welfare impact estimates of the variation in household asset endowments. This thesis therefore provides new and more solid evidence on the welfare affects of access to different assets in rural areas of Uganda based on rich panel data set. It makes a contribution to a body of literature that seeks to enhance returns to investment in such productive assets for economic growth in developing countries.

When faced with the challenge of reducing income uncertainty, households tend to allocate their resources to activities with lower expected marginal value product than they would in absence of uncertainty (Roe & Graham-Tomasi 1986). This thesis conjectures the extent to which rural farm households are able to cope with productivity risk that is largely created by the effects of the idiosyncratic shocks to asset endowments. However, the thesis does not assess the effects of covariant production shocks such as drought due to data limitations on this information. The expected and unexpected shocks such as; sickness, deaths, thefts, changes in weather, pests, diseases, and price variability create fluctuations in rural household incomes and consumption levels (Deaton 1997). In response, households adopt informal methods of income smoothing to protect themselves from effects of such shocks that can also have implications on their welfare overtime. In particular, whilst empirical evidence on the effects of idiosyncratic shocks on household welfare in developing countries is found to be largely counter-intuitive, households tend to smooth the effects of idiosyncratic shocks than the negative effects of covariant shocks (Porter 2006). Therefore, whether rural households can utilize their assets efficiently to increase their income levels, amidst the risk of unexpected shocks to assets and other factor market imperfections, including liquidity and subsistence constraints, is an empirical question that this thesis attempts to evaluate in a robust way.

The ultimate pathway out of poverty may go through increased savings and asset accumulation (Deaton 1991; Deaton 1992b; Rosenzweig & Wolpin 1993; Sherraden 2001; Zimmerman & Carter 2003). When faced with uncertainty, rural households may hedge against this risk and liquidity constraints by accumulating assets as a buffer stock strategy. There can also be a positive and significant correlation between changes in wealth and changes in the demand for assets including education (Glewwe & Jacoby 2004). Poor households that have limited endowments of wealth can then face credit rationing in the imperfect formal credit market, which creates significant constraints to getting out of poverty. There can also be a positive correlation between wealth and marginal returns to investment, due to increasing returns to scale and the importance of fixed costs or risk (Adato et al. 2006; Carter & Barrett 2006), but this may not true when asset losses are large enough to undermine asset accumulation. This dissertation is therefore concerned with asset-based coping strategies of rural households, and whether they are able to utilize their productive asset endowments to improve their welfare over time. Moser (2006) indicates that household productive assets may include tangible and intangible endowments that can be accessed, developed, improved and transformed across generations to generate consumption and additional stocks.

Conceptual Framework

This section provides a conceptual framework that analyses rural livelihood development and poverty reduction based on asset accumulation and related coping strategies. Livelihoods represent a holistic picture of complexities of survival, and in the low income countries, this may include income levels, access to assets, sustainability issues, partnerships, and employment. Ellis (2000, p.10) defines livelihood to comprise the three main dimensions of asset endowments (natural, physical, human, financial and social capital), the activities and processes of access to and utilization of these assets (mediated by institutions and social relations) that together determine the survival strategies and the welfare gained by the individual or household.

The foundations of the conceptual framework

The framework in this thesis builds on the theory of the new institutional economics (NIE) that consider economic outcomes, especially in the developing countries, to be largely dependent on the combined effects of market imperfections and the fundamental forces of resources, technology and preferences (Hoff & Stiglitz 2001). The NIE relaxes the unrealistic assumptions of neo-classical[3] economic theory such as perfect information, zero transaction costs, unimportance of institutions, perfect enforcement of contracts, and full rationality. It instead emphasizes the importance of transaction costs, environmental factors, the endogenous nature of institutions and institutional arrangements that determine economic exchanges and performance in any given community (North 1990; Bardhan 1993; Kherallah & Kirsten 2002; Vandenberg 2002). Institutions in a community may range from property rights, norms, and the corresponding relationships between individuals that define the participation as buyers, sellers, renters, landlords, tenants, workers etcetera. Strong institutions reduce transaction costs of market exchanges between people, and increase internal differentiation in wealth accumulation. They stimulate a system of fair negotiation, trust, and enforcement of contracts that foster further investment and local trade.

[3] In the narrow perspective and just for convenience, neoclassical theory can be described to represents economic models that postulate maximising agents, who also interact through a complete set of competitive markets (Hoff and Stiglitz, 2001). It also includes the early work in institutional economics that perceived institutions to be crucial in creating efficiency by filling in for missing markets. It asserts that economic outcomes are determined by the fundamental forces of resources, technology and preferences, yet its implications in the real world with diffuse externalities are found to be quite misleading due to the inability to explain key aspects of behavior and development process (Hoff and Stiglitz, 2001)

Production relations (the nature of different asset markets) in tropical agriculture contribute to market imperfections. They are determined by the joint combination of: (i) rural economic factors such as the consequences of risk, information costs, and seasonality, and changes in material[4] and technological features of agricultural production, and (ii) biophysical attributes of productive assets that range from mobility, maintenance cost requirements (fragility), suitability as collateral, the relevance of incentive problems, divisibility, and time (gestation) required to produce the asset (Binswanger & Rosenzweig 1986). In land scarce communities, production relations may establish improper incentives and problems of asymmetric distribution of information, moral hazards, adverse selection and inadequate screening mechanisms (to discern the likelihood of effort), imperfect enforcement of property rights, incomplete insurance markets, and capital constraints (Binswanger & Rosenzweig 1986; Hoff & Stiglitz 1990). In turn, the behavioural responses to these problems influence the features of the distribution of ownership, use of productive assets, and the choice of contractual arrangements for short-term rental, long-term rental, and sales transactions.

The joint effect of transaction costs, covariate risk, and asymmetric information (moral hazard and adverse selection problems) lead to market imperfections that may include; missing markets, thin markets (imperfect competition), partly missing markets (rationing, seasonality), limited access to credit, access to informal credit at high interest rates, constrained access to off-farm employment, price bands on output and labor, interlinked (input, credit and output) markets, and constrained access to rental markets of assets such as land (Holden & Binswanger 1998; Holden et al. 1998; Holden et al. 2005). The combination of market imperfections and uninsured risk create inefficiencies and fluctuations in household income, and can also limit the ability of households to take on profitable activities that reduce income poverty (Dercon 2002; Dercon 2005). They impose constraints on input demand, output supply, investment in asset building, and consumption smoothing processes. To the extent therefore, that significant market imperfections exist in the local markets, including markets for insurance and external credit, rural households respond by accumulating buffer and productive assets to provide safety nets. This strengthens the ability of households to maintain and expand their welfare over time.

[4] Material features of agriculture may include the spatial nature of agriculture (dispersed, with low or high population density), the existence or absence of technical economies of scale (level of technology), the resulting covariance of risks (seasonal rainfall), and the distinct attributes of each factor or productive asset (Binswanger and McIntire 1987, Binswanger and Rosenzweig 1986).

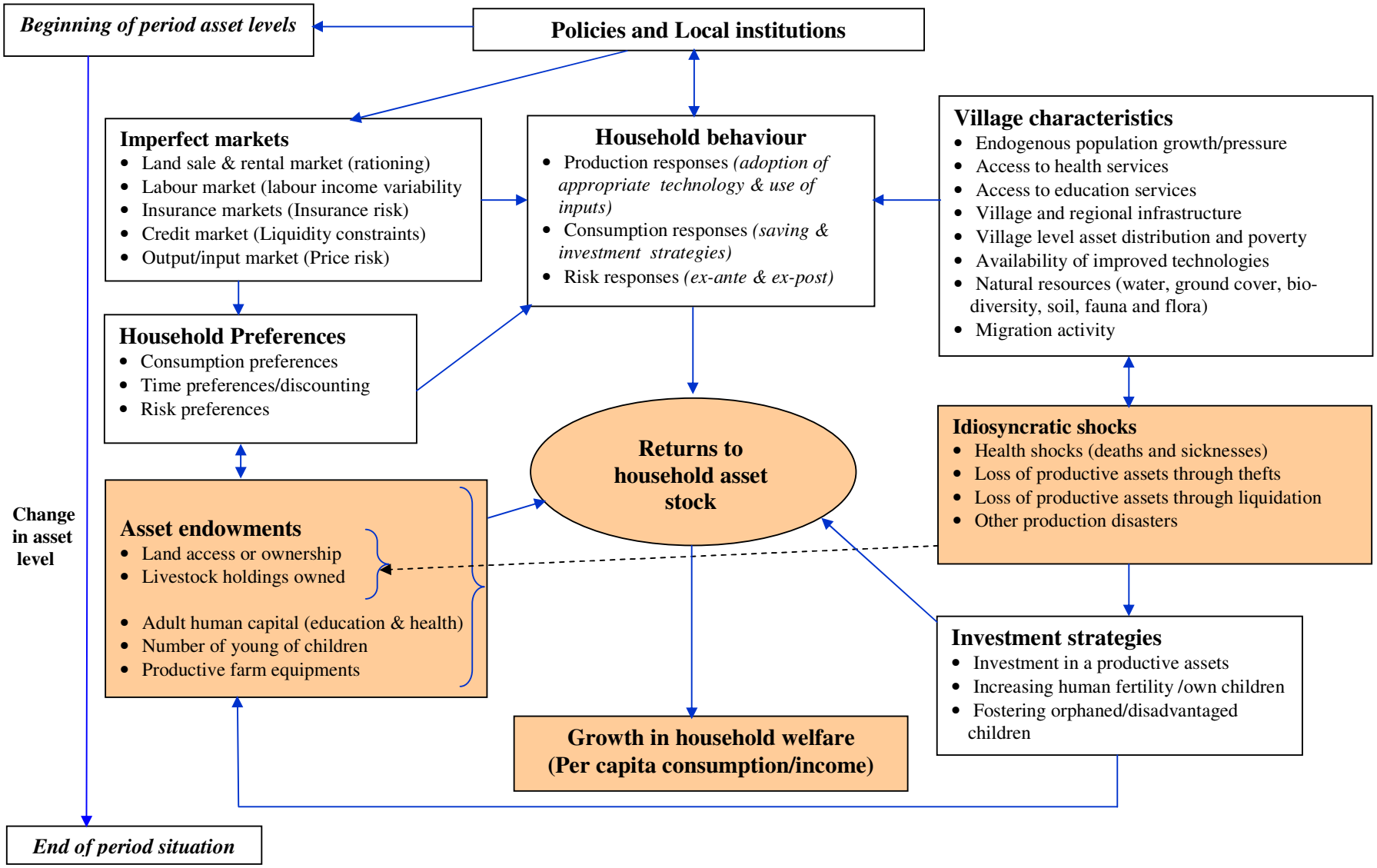

Figure1. Change in productive asset endowment, idiosyncratic shocks, asset-based risk coping strategies and household welfare

The conceptual framework (Figure1) shows linkages between policies, institutions, markets, technology, vulnerability issues and access to assets that are all vital for sustainable development. These interactions define effective supply and demand for market and non-market outputs, opportunities and constraints that rural households face. The presence of markets[5] for inputs and outputs can create a broad-based rural development through better exchange of assets, goods and services. Conversely, the joint combination of imperfect markets and information asymmetries in rural areas create high transaction costs in virtually all output and input markets (de Janvry & Sadoulet 2005). This in turn, creates direct interrelations (nonseparability) between production and consumption, which further limit quantities that can be exchanged and the level of market participation (Singh et al. 1986; de Janvry et al. 1991; Sadoulet & de Janvry 1995; Key et al. 2000).

The implications of the conceptual framework

The framework also incorporates insights from the work of previous studies (Deaton & Muellbauer 1980; Deaton 1990; Deaton 1991; Deaton 1992a; Rosenzweig & Wolpin 1993; Zimmerman & Carter 2003; Kazianga & Udry 2006). These studies examine the ability of households to manage risk and to smooth consumption in areas that are characterized by incomplete formal financial markets, absence of insurance contracts, and ubiquity of credit and liquidity constraints. Attanasio and Weber (2010) report that the unanticipated changes in income level that are relatively permanent can stimulate substantive changes in household consumption. This may not be the case, when changes in household income are expected and temporally in nature.

Households are assumed to have access to natural resources, human capital, on-farm physical capital, and off-farm physical capital at the beginning of each period. As producers, households maximize the utility of the returns to assets, given the production function and other constraints. The decisions to produce, consume, and supply labor become interrelated in the presence of imperfect markets and information asymmetry. Households typically wish to achieve high levels of income and to smooth their consumption over time, but cannot borrow for consumption purpose. Liquidity-constraints prevent young households from borrowing against future labor income to finance higher current consumption (Fernández-Villaverde &

[5]The absence of markets and the effects of markets in rural areas influence livelihood opportunities and constraints that arise from market processes. Conversely, institutional change may determine pro-poor market development (Dorward et al. 2003), whilst market development is also part of institutional development.

Krueger 2007). Households also face risk from production process to marketing, including income uncertainty created by idiosyncratic health shocks. They are generally averse to risk, with the degree of risk aversion varying among households and between levels of wealth. They manage their assets in order to avoid the disaster of ever falling below certain minimum consumption levels and to avoid other unexpected disasters. Households may lose labor power through ill-health and deaths when consumption drops below a critical subsistence level (Zimmerman & Carter 2003). Households therefore plan consumption for the present and future periods based on their wealth, expectations about the future productive assets, and the related discounted future income streams.

Household response to risk

Risk is a measure of uncertainty and can be quantified in form of variance in income, probability of loss, and size of maximum possible loss. Idiosyncratic health shocks can affect asset accumulation. In this thesis, health shocks include illness of household members and death incidences. Inadequate data on multiple shocks did not allow the assessment of welfare effects of covariant risk generated by village-specific production disasters, thefts, aversion towards taking credit for input use, and other idiosyncratic risk.

A combination of farmers' aversion to risk, liquidity and borrowing constraints in rural areas may result into output losses, lower efficiency, lower average incomes and volatility in incomes (Rosenzweig & Wolpin 1993). Risk aversion and limited access to consumption-smoothing mechanisms can influence the composition of household asset portfolios (Rosenzweig & Binswanger 1993). And while the current income may influence how households formulate expectations about their future income (Deaton & Muellbauer 1980), access to credit offers households with immediate means to pay for consumption and investment. Households choose to access credit when their income flows fail to correspond to the desired consumption pattern or when their income fluctuates with external shock (Sadoulet & de Janvry 1995). This implies that liquidity constrained households have higher marginal propensity to consume and are likely to spend any resource that is available.

Liquidity constraints also create systematic difference in savings and consumption behavior across households. Households with enough initial assets or high current incomes may not need to borrow, and can easily access credit if they wish to do so, unlike households with limited initial assets. Lenders in rural areas face high cost of administering credit. They may not

observe the ability of potential clients to repay their loans due to imperfect information. In risky environments, lenders rely on inadequate screening procedures that depend primarily on the nature of observable characteristics considered to be correlated with creditworthiness. A substantial proportion of households is therefore rationed out of credit market due to possession of unfavorable social status, employment, sex, and age (Deaton & Muellbauer 1980).

Household responses to uncertainty and production decisions largely depend on household time preferences, risk preferences and consumption preferences[6] (discount rates), especially when markets are imperfect or missing. Risk preference determines the behavior of a household when dealing with potential losses as a result of the prevailing risk. A risk-averse producer would prefer to attain sure income to the uncertain income of the same average value, even when uncertain income is considered to have higher expected utility than that of certain income for risk takers (Sadoulet & de Janvry 1995). Household behavior therefore reflects actions that are adopted in order to cope and mitigate risks in agricultural production and consumption, and in turn play a significant role in determining the level and composition of income flows (Reardon & Vosti 1995). Households adopt various ex-ante and ex-post risk coping mechanisms, including intercropping, grain storage, sharecropping, engaging in social relationships and asset accumulation. These provide affordable insurance in many ways to bear the large degree of residual risk that has to be born at individual household level.

The conceptual framework (above) reveals that household consumption behavior is determined by the total household income and resources at hand. This implies that households with high rates of time preference focus on the well-being in the present and immediate future, while those with low rates of time preference place more emphasis than average on their well-being in the further future. Conversely, households with high consumer preference select and focus on consumption options with the greatest anticipated value.

The influence of children

Households are forward looking in making provision for the future consumption needs and possible falls in income, especially when children are in a household. A vast economic

[6] Time preferences or discounting refers to how large a premium a household is able to place on enjoyment nearer in time over more remote enjoyment. Consumer preferences indicates how more valued consumption choices are made from alternative options, while risk preferences indicate whether a household can rather risk big losses than suffering a certain moderate loss.

literature on life-cycle consumption expenditure suggest that changes in household size and other characteristics explain growth of consumption over a household's life cycle (Blundell et al. 1994; Attanasio et al. 1999; Fernández-Villaverde & Krueger 2007; Browning & Ejrnæs 2009). Arguably, demographic[7] characteristics may explain to some extent why consumption tends to track income over the life cycle. The path of demographics over the life cycle is shown to display similar patterns of consumption. This implies that the presence of children in households might impact on consumption by removing excessive correlation between consumption and income (Browning & Ejrnæs 2009).

The correlation between consumption and income can partially be explained by the parental care about the present and future well-being of their children, who are also highly regarded as a special type of capital asset (Cigno et al. 2002). Although, parents cannot determine the number and timing of births with certainty, they are more interested in the number of children that can survive into adulthood. Yet, beyond the survival instincts, children are better off going to school compared to engaging in remunerative work whether at home or elsewhere. This makes altruistic rural households to possibly send their children to work, only if the household income falls below certain critical level.

This thesis therefore posits that changes in productive asset endowments of operated land, livestock, farm equipments, human capital, and the number of young children can increase the ability of households to generate income flows in each period of the life-cycle. This in turn determine the level of household consumption, welfare, further asset accumulation, and income diversification that are essential to reduce poverty over time. This dynamic process is further supported by local institutions, village and regional characteristics such as population density, access to public services, village-specific infrastructure and natural resources. The analysis in this thesis does not cover the whole life cycle dynamics of income generation and consumption smoothing, and neither does it distinguish the effects of the increase in asset endowments from the effects of decrease in these endowments. Ultimately, the analysis does not assess whether some households are caught in a poverty trap and what causes some to fall into poverty and others to climb out of poverty.

[7] The hum in consumption-age profiles is reported to be determined by the combined effects of uncertainty responsible for the delay in consumption and demographics that can increase the marginal utility of consumption during the period when children are in a household (Blundell et al. 1994). Attanasio, et al (1999) indicate that when uncertainty is neglected, the life cycle model produces consumption profiles that are too flat. On the other hand, neglecting demographics generates consumption profiles that peak rather too late in the life cycle.

The general inter-temporal choice problem

An inter-temporal framework that shapes the ability of households to maximize utility over-time, subject to a set of intertemporal trading opportunities can be formulated. Consider a household h at time t with access to a vector of productive assets, A_{ht} comprising of land operated, human capital, young children, livestock, and productive farm equipments. The household seeks to maximize a sequence of consumption $C_t, C_{t+1}, \ldots$ and investment $I_t, I_{t+1}, \ldots.$ in productive assets in each year to help maximize the discounted stream of expected welfare.

The household problem is to maximize the expected present discounted value of lifetime utility, $u\left(C_t - C_{\min}\right)$ conditional on the information available at time zero over a finite horizon[8], with $C_t - C_{\min}$ indicating the difference between total consumption of a single commodity C_t and the absolute minimum needs in each and every period. The new information in each period allows the household to choose new consumption and investment subject to a corresponding budget restriction, but the rate of return on the vector of productive assets is unknown.

Let the preferences of the household in each period that inform the maximization problem be represented by an isoelastic (constant relative risk aversion i.e. is CRRA) utility function denoted by, $u(C_{ht}) = \left(C_{ht}^{1-\gamma} - 1\right) \big/ \left(1-\gamma\right)$ when $\gamma \to 1$. This allows the utility function to converge[9] to the first-order conditions that are log-linear in consumption $\ln\left(C_{ht}\right)$ and also to reflect risk aversion when, $u^{"} \le 0$. The expected additively separable inter-temporal utility of a stream of consumption, C_t takes the form:

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[8] Assume that the bequest motive may not be empirically important i.e. $A_{hT} = 0$, the household consumes all the wealth and income.

[9] The CRRA utility function is increasing in $C_{ht}^{1-\gamma}$ if $\gamma < 1$ but also decreasing in $C_{ht}^{1-\gamma}$ if $\gamma > 1$. The denominator $1-\gamma$ allows the marginal utility to be positive for all values of γ (Bergman, 2004). Therefore, by subtracting the constant $1/\left(1-\gamma\right)$ from the CES utility function, $u(C_{ht}) = \left(C_{ht}^{1-\gamma}\right) \big/ \left(1-\gamma\right)$ (*the L 'Hôpital's rule*) allows the solution of the problem to drop out and thus, simplifying the differentiation procedure (Pradhan, 2002) to $\lim_{\gamma \to 1}\left[\left(C_{ht}^{1-\gamma}\right) \big/ \left(1-\gamma\right)\right]$, $= \lim_{\gamma \to 1}\left[\left(C_{ht}^{1-\gamma}\right)(-\gamma)\ln\left(C_{ht}\right) \big/ (-1)\right]$, $= \ln\left(C_t\right)$, for $\gamma = 1$ .Other class of utility functions in the intertemporal models may include the Exponential or Constant Absolute Risk Aversion (CARA) and the Quadratic Utility Function.

$$J^{*}\left(A_{h0}\right) \equiv \max_{\{c,I\}} E_0 \sum_{t=0}^{\infty} \delta^{t} \frac{1}{1-\gamma} u\left(C_{ht} - C_{\min}\right)^{1-\gamma} \tag{1}$$

where E_0 is the expectation operator given the information set at time, $t=0$, δ^{t} is the household discount factor $\left(1/1+\beta\right)^{t}$ that measures patience (i.e. the idea that the present may matter more than the future), with β denoting the utility discount rate (rate of time preference), $\gamma > 0$ is the relative risk aversion parameter summarizing the attitude of the household towards risk. Concavity of the utility function caused by a positive value of the coefficient of the relative risk aversion, γ, are two sides of the same coin and a high level of risk aversion, γ, implies a more concave utility function, and this creates a strong desire to smooth consumption by accumulating productive assets, whose return can be used to provide for the future consumption. The utility function $\left(u(C)\right)$ is therefore increasing in consumption and is strictly concave such that $u^{'}(C) > 0, \quad u^{''}(C) < 0$.

By making use of a Bellman's equation that reduces the complexity of the recursive optimization problem into smaller sub-problems representing a two-period problem, the dynamic optimization problem (equation 1) can be stated as:

$$J_{t}^{*}\left(A_{ht}\right) \equiv \max_{\{c_{ht}, I_{ht}\}} \left\{ \frac{1}{1-\gamma} u\left(C_{ht} - C_{\min}\right)^{1-\gamma} + \delta^{t} E\left[J_{t+1}^{*}\left(A_{ht+1}\right)\right] \;\middle|\; t \right\} \tag{2}$$

Subject to:

The budget constraint defined as the purchasing power of the household, as a function of productive assets and the stochastic income shock θ_{ht}^{k}:

$$C_{ht} - C_{\min} = F\left(A_{ht}, \theta_{ht}^{k}\right) - p_{x}^{A} I_{ht} \tag{3}$$

The transition equation indicating how the productive asset levels, A_{ht} evolve over-time in response to investment decisions and stochastic asset shocks Θ_{ht},

$$A_{ht+1} = R_{ht}\left(A_{ht} + I_{ht} - \Theta_{ht}\right) \tag{4}$$

A_{h0} is given

The borrowing constraint that restricts tradable asset endowments to be non-negative at the end of each period

$$A_{ht+1} \geq 0 \tag{5}$$

where $J^*(A_{ht})$ is the true Bellman[10] value function for the underlying infinite horizon optimal problem that defines the maximum discounted stream of future livelihoods that household h can expect, p_x^A denotes a vector of local market prices upon which the productive assets can be liquidated (or the cost of irreversible productive assets), while, R_{ht} denotes the return on the household's vector[11] of productive assets. The Bellman equation is able to satisfy a contraction mapping theorem that is crucial in finding the unique and unknown true value function $J^*(.)$ numerically. The household faces a tradeoff between the current utility $u(C_t - C_{\min})$ and future wellbeing $\left(J^*(A_{ht+1})\right)$.

Noteworthy, the assumption of the constant relative risk aversion utility function, the complex nature of investment and production decisions and the presence of multiple non-linearities due to market imperfections make the solution of this optimization problem analytically intractable (Rosenzweig & Wolpin 1993; Carter & Zimmerman 2000; Carter & May 2001; Zimmerman & Carter 2003; Attanasio & Weber 2010). The true value function can only be derived through a simulation procedure using numerical methods that is beyond the scope of this thesis.

It is possible though, to utilize the first-order conditions (the Euler equation approach) of the inter-temporal optimization to derive testable hypotheses (Hall 1978), and to circumvent the need to derive closed form solutions that are analytically intractable. Simulations can then be employed to quantify values of different structural parameters, but some features may require the derivation of consumption function numerically. With several substitutions into the Bellman equation and using the property that, $J_{t+1}^{*'}(A_{ht+1}) = U'(C_{t+1})$ equation (2) can be rewritten as:

$$J_t^*(A_{ht}) \equiv \max_{\{c_{ht}, I_{ht}\}} \left\{ \begin{array}{l} \frac{1}{1-\gamma} u(C_{ht} - C_{\min})^{1-\gamma} + \\ \delta^t E\left[J_{t+1}^*\left(R_{ht}\left[F(A_{ht}, \theta_{ht}^k) - (C_{ht} - C_{\min}) + (A_{ht} + \Theta_{ht}) \right] \right) \right] \end{array} \middle| \; t \right\} \qquad (6)$$

[10] The Bellman's principle of optimality represents the self-enforcing character of the household optimal plan in any period (t), such that the optimal plan over the next remaining period (s+1) is also optimal.

[11] Labor income is not explicitly included in budget constraint, given the market value of tradable human capital that is in this case included in the vector of household productive assets (see Campbell (1996) for similar specification).

The first-order conditions with respect C_{ht+1}:

$$U^{'}\left(C_{ht+1}\right)=\delta^{t}E(R_{ht})U\left(C_{ht+1}\right)^{'} \tag{7}$$

Differentiating equation (6) with respect to $A_{ht,t+1}$:

$$\delta^{t}E\left[\left(R_{ht}\right)U^{'}\left(C_{ht+1}\right)\right]=0 \tag{8}$$

From the first-order conditions, it is possible to ascertain the true value function of the optimization portfolio problem by setting[12]

$$J_{1}^{*}\left(A_{hs+1}\right)=J_{2}^{*}\left(A_{hs+1}\right), \tag{9}$$

The consumption-investment trade-off is then solved by setting:

$$u^{'}\left(C_{ht}-C_{\min}\right)=\delta^{t}J_{1}^{*}\left(A_{hs+1}\right) \tag{10}$$

where J_{i}^{*} is the first derivative of J^{*} with respect to i^{th} argument, but the closed form solution of this problem is not attainable, given that J depends on household endowment of productive assets. The second-order Taylor expansion of the Euler equation (first-order condition) for optimal consumption choice that relates marginal utility today to expected marginal utility tomorrow (Ludvigson & Paxson 2001) can be adopted to give the estimating equation for the optimal consumption and portfolio shares that is vital for the poverty reduction:

$$\Delta C_{ht+1}=\delta^{t}E\Delta\left(R_{ht}A_{ht+1}\right) \tag{11}$$

A linearized (log-linear) version of the Euler equation that indicates the trade-off between the current consumption and asset accumulation for future consumption can be estimated on the panel data:

$$\Delta C_{ht+1}=\mu_{h}+\beta_{h}\Delta A_{ht+1}+\varepsilon_{ht}, \qquad \text{with } E_{t}\left[\varepsilon_{ht}\right]=0 \tag{12}$$

where μ_{h} is the household specific intercept term that is assumed to be constant, and whose size reveals the extent to which household consumption depends on other sources of income other than the endowments of productive assets. The coefficient β_{h} represents the degree of responsiveness (elasticity) in the level of household consumption as a result of a 1 percent increase in the level of productive assets. The larger the β_{h} the more important are the effects of change in the level of productive asset endowment and related change in returns to assets in explaining consumption smoothing and household welfare. Household consumption decisions to allocate resources therefore depend on the total amount of productive assets (such as current income, level of current assets, future income, and level of future assets), preferences over

[12] The other preference parameters such as the discount factor is not identified in this type of framework, given that it gets buried in the time varying term that also depends on the preference parameters δ and γ.

different commodities, relative prices, profits, costs, risks, interest rates and intertemporal trade opportunities.

A synthesis of the empirical implications of the conceptual framework explained above can be provided in terms of relative poverty reduction impacts of different productive assets and their respective interaction effects (synergies) that characterize the use of these assets as either complements or substitutes in a household production process. A production function that allows use of several productive assets as factor inputs can be estimated to give the "marginal effects" of each productive asset. The "marginal effects and various interactive effects" of the productive assets can be derived from the translog formulation of production model as indicated below.

Household production function

The income and resources available for rural agricultural households depend on production activities (Singh et al. 1986), and profit maximization based on the endogenous decision price and output (Sadoulet & de Janvry 1995). To the extent that income is endogenously determined provides the opportunity to model the production side of farm households to assess the effect of exogenous production shocks on consumption (Jacoby & Skoufias 1998). The production function shows the maximum output that can be produced from any combination of productive capital. Given a certain level of output relative to prices of assets and the possibilities of substitutions among productive assets, households choose a bundle of land and nonland productive assets in a way that minimises the total cost of production.

A primal transcendental logarithmic (translog) production function framework that was formulated by Christensen et al. (1973) can therefore, be adopted to define the elaticity of complementarity between productive assets. The function allows richer specifications of the relationships between household income and productive assets and the associated interactions between assets (Dwyfor Evans et al. 2002) that are vital in enhancing household productivity and welfare. Being nonhomothetic, the translog production function does not require the assumptions of homotheticity and separability.

A household $h(=1,...,N)$ in year period $t(1,..,T)$ operating under conditions of perfect competition on both product and factor markets has a concave, twice differentiable translog

production function that relates the flow of total quantity of household output, y_{ht} and the effects of five productive assets, $A_{iht}\left(i=1,...I\right)$ in each year. The log transformed vector of productive assets include: operated land$\left(A_L\right)$, human capital$\left(A_H\right)$, child (labor) endowment$\left(A_C\right)$, livestock$\left(A_V\right)$, and farm equipments$\left(A_M\right)$. The farm household income from output is represented by the total household expenditure that is a reliable measure of welfare.

$$y_{ht} = F\left(A_L, A_H, A_C, A_V, A_M\right) \tag{13}$$

The translog production function can be written as:

$$\ln y_{ht} = \ln a_{0ht} + \sum_{i=1}^{n} \alpha_{iht} \ln A_{iht} + \frac{1}{2}\sum_{i}\sum_{j} \gamma_{ijht} \ln A_{iht} \ln A_{jht} \quad i \neq j; i, j = 1,..., I \tag{14}$$

where y_{ht} is the log of household output, and A_i is the log of the productive asset, i: α_{iht} and γ_{ijht} are the parameters of production function to be estimated and, $\gamma_{ijht} = \gamma_{jiht}$. The effect of change in the time trend can be considered to be a reliable measure of technical change (Kim 2000). Here, the marginal[13] effects indicate a proportionate increase in output for the relative increase in factor assets.

Following the previous of work of Kim, 2000; Nagarajan et al. 2002, the translog production function can be shown to generate the uncompesated inverse demand functions and Hicks elasticity of complementarity. The uncompesated inverse demand functions can then be used to estimate the Antonelli elasticity of complementarity (AEC) (see more details in Kim, 2000) that is considered to be a true dual of the Allen-Uzawa elasticity of substitution (AES) under non-constant returns to scale (Blackorby & Russell 1981; Kim 2000). The alternative, Hicks elasticity of complementarity (HEC) was previously considered to be dual to the Allen-Uzawa elasticity of substitution (Hicks 1970; Sato & Koizumi 1973). It measures change in the price ratio for a change in input ratio holding the quantities of other inputs constant and output price constant. The two elasticities can discriminate between assets that are substitutes and assets that are complements in production process of a household. Each of the AEC and HEC is positive for assets that are compliments and negative for assets that are substitutes.

[13] The marginal product of an input is calculated by differentiating the production frontier with respect to the logarithm of input to derive the logarithmic marginal product and then multiplying it by the average physical product of that particular input (Kalirajan, 1990).

2.1. Land Asset Endowments and Access

This section provides a discussion of relevant economic literature on household access to land, economic development and poverty reduction in developing countries. A recent study, Finan *et al.* (2005) shows that the ability of a household to generate sufficient economic livelihood may depend on land endowment, with access to a small amount of land able to permit the mobilization of family assets to create large income gains, even among the poor. This implies that land acquired through markets or otherwise may play an important role for rural household welfare (de Janvry et al. 2001; Pender et al. 2004b; Otsuka et al. 2007). In particular, land rental markets become important to the rural poor, especially when land distribution is in-egalitarian, and credit and other non-land factor markets are imperfect (Holden et al. 2008c). Land rental markets may be active even in countries where land distribution is egalitarian such as Ethiopia, when the important non-land productive resources have a more inegalitarian distribution.

It is widely recognized that small land holders enjoy the advantage of lower-cost family labor and managerial skills, while owners of large land holding face scale diseconomies that are created by the use of hired labor. In this context, better functioning land rental market can benefit both the small and large land holders by shifting the operational and ownership land holdings to the optimal operational size (Binswanger & Rosenzweig 1986). Land markets may enable land transfers from less able to more skilled landless and near landless households that are also rich in non-land factors of production. Land rental markets therefore provide affordable means through which the land-poor gain access to more land to promote productivity and welfare (Deininger & Feder 1998; de Janvry et al. 2001; Nkonya et al. 2005; Deininger & Mpuga 2008; Holden et al. 2008c). However, when fixed rent is high, cash stricken households may get rationed our of fixed land rental markets, but can also access land through borrowing that is important in reducing the entry barrier to land market participation (Holden et al. 2008b). This facilitates the landless and the near landless households to access additional land through the market, and to eventually climb the agricultural ladder.

Land transfers are reported to stimulate investment on the land, improve the equalization of factor ratio adjustment, and promote productivity (Holden et al. 2008b). However, a study conducted in Uganda shows that land that is accessed through the land rental market tend not be well managed compared to own land (Nkonya et al. 2008) and suggested the need to adopt interventions that can promote land markets (short-term land rentals) together with sustainable

land management practices through agricultural extension and natural resource management programs. This is important, if the functioning of land rental markets is to reduce land degradation and instead enhance efficiency of land use. Furthermore, the realization of efficiency and welfare effects of land markets may also depend on the degree of imbalances in the factor ratio prior to land exchange, transaction costs in other factor markets, and the substitutability among factors of production.

The presence of high transaction costs may cause a significant proportion of rural households to be rationed out of land markets. Even households that succeed in participating in the land market, especially in high populated areas, may also fail to access adequate land to realize sufficient income gains (Melmed-Sanjak & Lastarria-Cornhiel 1998; Holden et al. 2008b). Conversely, while the land sales market tends to be associated with high land price to the disadvantage of poor households (Otsuka et al. 2007; Holden et al. 2008b), the poor who are also vulnerable to shocks may opt to sell their land out of distress. They may also fail to replace their disposed land, due to unfavorable local land prices, but this may not be a serious problem in rural Uganda, given the recent empirical evidence that land markets did not create land concentration (Deininger & Mpuga 2008). Instead, the land sales market was found to be crucial in providing households with opportunities to generate starting capital for other investments. Households with large land endowments may not have serious capital constraints since they are more likely to benefit from the local financial markets. Households can use land markets to overcome liquidity constraints and imperfections in other factor markets to enhance resource use efficiency.

There is limited vigorous and robust empirical evidence on how rental and sales markets impact on patterns of poverty in rural areas in developing countries including Uganda (Deininger & Mpuga 2008). Few robust studies have examined the efficiency implications of land access and participation in land markets in Uganda (Baland et al. 2007; Deininger & Mpuga 2008; Holden et al. 2008a; Nkonya et al. 2008). Access to land through land markets, especially the land rental market has been shown to have a significant effect on household land use efficiency, investments, and the ability of the poor to cope with shocks in rural areas that have high population density (Holden et al. 2008c). In particular, land-poor households can utilize land markets, especially rental markets to overcome the constraints of market failures for credit, insurance, and managerial skills. It is therefore important to understand welfare

effects of land access based on robust empirical studies that control for biases due to endogeneity and unobserved heterogeneity.

Finan et al. (2005) suggests that any meaningful analysis of data to produce robust estimates of the marginal poverty reducing value of land: (i) should not only specify income equation as linear, but also take care of possible non-linear relationship between land endowment and income for some households due to investment constraints, (ii) should not rely on income as a measure of poverty when actually it is very noisy and over-restrictive compared to consumption expenditure or a multidimensional measure of poverty, (iii) should account for the high degree of heterogeneity across rural households on how they utilize their land endowments. The panel econometric methods employed in this thesis handle these econometric challenges and produce robust estimates of welfare effects of access to land through the market and non-market means.

2.2. Human Capital Accumulation and Child Endowment

Human capital is defined in economic literature as the return to education and work experience, while human resources include the returns to both education and raw labor (Serageldin & Steer 1994). This implies that human capital constitutes the skills and knowledge (Schultz 1961) and the intangible stock of attributes and competencies embodied in individuals that facilitate the creation of personal, social, and economic well-being (Le et al. 2003). The stock of human capital embodied in the labor force can be expressed in money units using three closely related methods of the cost-based approach, income based approach, and educational stock-based approach that also includes literacy rates, school enrollment and mean years of schooling.

The cost-based approach is a retrospective method that evaluates human capital stock based on the historical costs required to produce the physical human, including child rearing costs and the costs of enhancing the quality of labor through investments in education (Kendrick 1976; Eisner 1985). Conversely, the income-based approach is a prospective method that evaluates human capital based on the earning power or expected returns to investment in individuals that are considered to be influenced by acquired skills and education (Graham & Webb 1979; Jorgenson & Fraumeni 1989; Le et al. 2003), and is able to compute human capital as the sum of all the future income streams that an individual expects to earn in his or her lifetime. The education units of time are therefore transformed and expressed as the human capital stock value in terms of money (Wößmann 2003). In this thesis, the income-based approach is utilized

to compute household human capital based on the individual earnings that are also influenced by acquired skills and education level. According to Le et al.(2003) the income method can also utilize literacy rates, school enrolment rates, and average years of schooling as inputs.

Human capital theory suggests that education raises incomes by increasing the productivity of workers. The accumulation of human capital can improve the efficiency of labor input in terms of quality, it can also boost overall technical efficiency in production and allocative efficiency of the household (Jolliffe 2002; Kurosaki & Khan 2006). Undoubtedly, the skills and knowledge acquired by people is considered to be a product of investment, and may have an economic value that makes households more efficient producers (Schultz 1961). However, past studies conducted in Uganda and other developing countries indicate mixed empirical evidence on the impact of education on the welfare of agricultural households (Appleton & Balihuta 1996; Fafchamps & Quisumbing 1999; Appleton 2001). The failure of such studies to demonstrate consistent evidence on the welfare impacts of education can be attributed to the absence of experimental data, use of small samples and weak econometric methods (Appleton et al. 1996). These factors makes it hard to verify the actual impact of education as opposed to that of omitted variables that may also be correlated with the ability to access education and related training.

There may be a threshold level of education below which rural households experience a meaningful response to agriculture productivity, while household with more educated members may choose to allocate their labor to non-farm activities in relation to their comparative advantage (Kurosaki & Khan 2006). In the case of Uganda, some studies have examined the impact of education attainment on household productivity and welfare (Bigsten & Kayizzi-Mugerwa 1995; Appleton & Balihuta 1996; Appleton 2001; Deininger & Okidi 2003). And while they virtually employed econometric methods that assumed education to be exogenous to household decisions, to the extent that they did not adequately control for the endogeneity of access to education and other asset endowments raises questions about the efficiency and consistency of their empirical results. It is therefore imperative to conduct more robust studies that effectively controls for the problems of omitted-variable (causation and reverse causality) bias, in order to give unbiased estimates. Appleton et al. (1996) points out that the pre-existing ability and not years of schooling might be correlated with productivity (the screening hypothesis), and that people may be earning higher incomes due to mere educational qualifications instead of the true acquired skills (the credentialist theories). It is therefore

crucial to take into consideration the effects of screening hypothesis and the problem of unobserved inherent abilities, if the true estimates of returns to schooling are to be derived systematically. Psacharopoulos and Patrinos (2002) also call for more robust evidence of education on earnings, especially in developing countries using quasi-experimental designs or better econometric methods.

The role of young children

Rural farm households face an important decision to either maximize short-term benefits of having more children at home to provide labor input in agricultural economic activities or to produce few children that can specialize in school activities and be able to generate high returns to their families in future. Children are reported to have a substantial effect on wealth accumulation, and can also play a crucial role in retirement planning (Ray 1998; Cigno et al. 2002; Scholz & Seshadri 2007). In contrast, the cost of child-rearing in terms of parental expenditure on schooling, clothing and other requirements may have a negative impact on the household per capita growth in consumption (Becker & Barro 1986). This implies that changes in the child-rearing cost can influence growth of per capita consumption across generations. An increase in parental incomes can also lead to a relatively large increase in parental expenditures on children to boost the desired quality. Thus, the demand for children tends to reduce with the increase in parental expenditure, since the cost of each child is directly related to the expenditure on each.

The majority of rural households in developing countries face imperfect labor markets and weak local institutions for social security. This makes children a valuable asset in a household especially for the future insurance (Ray 1998; Angemi 2002). The high level of consumption needs and low income today means that households may not afford to accumulate personal savings for their own retirement. Also, the possibility that children may not look after their parents in their old age in a society where this practice is expected and accepted can increase fertility to compensate for this contingence. Families in developing countries tend to be large in size, with many children that can be allowed to work when faced with poverty. A negative correlation between household income and household size is also often reported especially in developing countries, but the existence of size economies in household consumption cautions against any quick conclusion that larger families are poorer (Lanjouw & Ravallion 1995; Ray 2000). It is therefore not surprising that a study in Pakistan, by Bhalotra (2007) reveals that wage elasticity of work hours can be significantly negative for boys and insignificantly

different from zero for girls. This provides strong evidence that unlike girls, boys in Pakistan work in order to help their households to meet subsistence needs. This phenomenon can be explained by the nature of relative return to schooling.

Household access to micro-credit may also raise children's propensity to work especially during the season of peak labor demand (Hazarika & Sarangi 2008). Micro-credit can increase use of more capital equipment and other inputs in household enterprises, and may in turn raise the productivity of child labor. Empirical evidence shows that credit-stimulated enterprises can engage adults, and in turn compel children to replace adults in domestic chores (Hazarika & Sarangi 2008), but such a shift in child labor supply was not found to reduce school attendance of children. In the same vein, a recent study done in Ethiopia indicates that access to productive assets such as land and labor can increase the productivity and the demand for child work (Cockburn & Dostie 2007) that has significant implications on child time allocation. It is therefore likely that an increase in access to productive assets and higher returns to assets may encourage parents to withdraw their children from school to provide child labor.

A recent study in Ecuador found that child labor declines with the level of cash transfers even when the size of the transfer could not cover the foregone earnings (Edmonds & Schady 2009). In the case of Uganda, the elimination of school fees under the Universal Primary Education (UPE) that started in 1997 is reported to have increased the probability of a child (boys and girls) attending school before age 8 by 10% (Grogan 2006). There is need therefore, for effective policies that can reduce child labor and prevent extreme forms of child exploitation.

In the case of family planning policies, evidence on fertility behavior suggests that parents can make a trade-off between family size and human capital levels per child in response to changes in the relative costs and returns to increasing human capital investments (Rosenzweig 2000). An while households that prefer smaller human capital investments per child may not control fertility perfectly, the actual, desired and excess fertility levels can be high in societies where the parents are willing to pay a low shadow price (maximum price) for children. Although, there is still active controversy regarding the role of children in poverty reduction, a recent study Scholz and Seshadri (2007) argues in favor of the importance of children in influencing household welfare and wealth distribution, particularly when income risks are uninsurable and borrowing constraints considered to be binding.

2.3. Livestock Holdings and Productive Farm Equipments

The production and consumption of livestock and livestock products in Uganda and the rest of East and Central Africa (ECA) has been growing rapidly to the extent of creating a livestock revolution (Delgado et al. 1999; Kristjanson et al. 2004; Pica-Ciamarra 2005; Omamo et al. 2006). However, despite the comparative advantage in livestock production, poverty continues to loom large in these countries (Pica-Ciamarra 2005), implying that the prevailing markets, and policies lack sufficient impact to pull rural livestock producers out of poverty. The presence of markets for assets including livestock can improve the ability of the poor and the well-off households to cope with risk (Zimmerman & Carter 2003). Wealthier agents tend establish relatively high-return portfolios to be used in consumption smoothing in the wake of income shocks (Rosenzweig & Wolpin 1993; Carter & May 2001; Dercon 2002; Zimmerman & Carter 2003; Dercon 2005). On the other hand, poor households may pursue a defensive portfolio strategy characterized by both income smoothing and asset smoothing (Zimmerman & Carter 2003). This implies that risk management may be expensive for the poor in the long-run to the extent that poverty traps are created while smoothing income through either the accumulation of low return portfolios or destabilizing consumption to defend their asset base.

Recent studies in Uganda show that access to productive assets including livestock may provide rural households with a tremendous opportunity to generate income and to move out of poverty (Ellis & Bahiigwa 2003; Ellis & Freeman 2004; Lawson et al. 2006). Ellis and Freeman (2004) indicate that livestock ownership increases steadily with income ranges across households in Uganda. Riethmuller (2003) reveals that the loss of an animal for a small farmer may have severe consequences on his welfare, and the negative effects may spillover to other enterprises such as agricultural food production, if animals are used to plough the land. It is also reported that rural households in Uganda accumulated tremendous levels of livestock and household appliances in the 1990s (Okidi 2004), and this is in line with poverty reduction that was also registered in that period (1990-2000). Ownership of livestock is indicated to be an important determinant of well-being. A study conducted in Adjumani district in Northern Uganda shows that the odds of well-being above any given level is 2.4 times higher for households owning livestock compared to households that don't have livestock (Bashaasha et al. 2006). However, these studies did not control for correlations due to unobserved household heterogeneity and endogeneity of access to assets, which could have biased their estimates.

3. Data and Measures of Household Welfare

This study utilizes a three-period household panel data set surveyed in 2001, 2003, and 2005. The first survey was conducted in 2001 by the International Food Policy Research Institute (IFPRI), and covered two thirds of Uganda including Southwest, Central, and Eastern and some areas in Northern Uganda. A stratified sampling procedure was employed based on a classification of Uganda's territory according to the agricultural potential, market access and population density, A total of 450 households in 107 communities were interviewed in this IFPRI survey. The subsequent two surveys were conducted in 2003 and 2005 as part of the Research on Poverty, Environment, and Agricultural Technologies (REPEAT) project. In these surveys, 3 districts that part of the initial IFPRI study areas were dropped due to insecurity in the North and Northeastern parts of Uganda. Instead 94 out of 107 IFPRI study communities in 2001 were selected. This change in the sampling frame in 2003 survey meant that only 333 households out of the 450 households in the baseline survey of 2001 be included in the 2003 REPEAT survey.

In 2005 REPEAT survey, 20 more households dropped out of the 333 households. Six to nine household that had unusual and conflicting information on land endowment and agricultural production in at least one of the three periods were also dropped out of the analysis. The analysis is therefore conducted on a balanced panel data of maximum 309 rural households, 927 observations in 26 districts that include; Mubende, Luwero, Nakasongola, Masaka, Mukono, Kayunga, Rakai, and Mpigi in the central region; Sironko, Tororo, Bugiri, Iganga, Mayuge, Jinja, Kamuli, Pallisa, Mbale, Busia, and Kumi in the Eastern region; and Mbarara, Kabale, Kisoro, Kabarole, Kasese, Bushenyi, and Rukungiri in the western region of Uganda. This makes the findings of this thesis relevant to the rest of Uganda (see map below), and also to other similar countries in the region of Sub-Saharan Africa.

Several diagnostic tests in form of scatterplots, lowess, and local linear regressions were conducted to verify the appropriateness of the model specifications and the adopted functional forms between the household welfare measure and each of the key productive assets. In addition, the endogeneity of each asset was tested using a Robustified Durbin-Wu-Hausman (DWH) method (Cameron and Trivedi 2009, p.189-190). The correlation matrices and graph matrices of explanatory variables that are specified in the estimated models were also evaluated and found to be within acceptable range. And while all these test results indicated that the data is of high quality, they also justify the use of different panel models that give more reliable and

less biased estimates in this thesis. The details of these tests and their respective results are summarized in the extended Appendix A1-A5 at the end of this thesis, p.218-253.

Figure 2 The map of Uganda showing administrative units of at district level in 2009 and 2010

3.1. Measures of Household Welfare

We computed income per adult equivalent and expenditure per adult equivalent as measures of household welfare (poverty levels). Income[14] reflects the consumption opportunity gained by a household or an individual within a specified time frame. In this thesis, household income in a year was computed from the: summation of the value of home crop production net of the cost of inputs, value of home produced livestock that were consumed, cash income from sale of livestock and livestock products net of livestock production costs, and cash income from seasonal and monthly off-farm activities. On the other hand, household total expenditure was constructed from cash expenditure for consumption and value of consumption of home produced goods. The two measures of household poverty levels were adjusted to 2005 prices.

Households exhibit differences in size, age composition, educational level, which may create differences in expenditure patterns. The real household income and expenditure variables are therefore normalized to adult-equivalents[15], in order to make meaningful comparisons across households. Part of the data limitations in this thesis is that real annual income of households in 2001 is indicated to be much lower than the corresponding real annual consumption expenditure, and this can be attributed to practical difficulties in measuring income of rural households that tend to be self-employed in agriculture. Consumption is considered to be a better measure of lifetime welfare compared to current income (Deaton 1997), and the validity of evidence provided by this thesis can be regarded to be more credible with household consumption expenditure measure of welfare than is the case with the income measure.

3.2. Descriptive Statistics of Key Variables in this Thesis

A summary of key welfare and asset variables in this thesis are summarized in Table 1. Household income per adult-equivalent increased steadily on average from approx. Ug.shs 214,000 in 2001 to Ug.shs 376,000 in 2005. During the same period, household consumption expenditure increased slightly from Ug.shs 345,000 to 387,700. On average, 0.64 acres of land per adult-equivalent was accessed through land renting, borrowing and purchases compared to 0.5 acres of land per adult-equivalent that was acquired through inheritance.

[14] Economic literature, defines factor income as the flow (measured per unit of time) of revenue accruing to a person, a household or an entity from labor services and ownership of land and capital. Income is also defined in consumer theory as the budget constraint, the amount of money to be spent on different quantities of goods with different prices.

[15] Adult-equivalents are scales that are based on nutritional requirements of household members as determined by experts.

Table 1: Summary of Key Variables in this Thesis

	2001		2003		2005		Overall	
	N	Mean	N	Mean	N	Mean	N	Mean
Per adult-equivalent (AE)								
Household income per adult-equivalent /10000 (Ug.shs)	309	21.35 (1.73)	309	34.02 (2.87)	309	37.60 (2.46)	927	30.99 (1.40)
Household expenditure per adult-equivalent /10000 (Ug.shs)	309	34.50 (1.50)	309	38.61 (3.78)	309	38.77 (2.02)	927	37.29 (1.52)
Land owned per adult-equivalent (acres)	309	1.04 (0.07)	309	0.98 (0.08)	309	1.24 (0.10)	927	1.09 (0.05)
Land operated per adult-equivalent (acres)	309	1.12 (0.07)	309	1.05 (0.08)	309	1.31 (0.10)	927	1.16 (0.05)
Land inherited per adult-equivalent (acres)	256	0.54 (0.05)	256	0.51 (0.05)	256	0.45 (0.04)	768	0.50 (0.03)
Land acquired through renting and borrowing per AE (acres)	174	0.16 (0.03)	174	0.15 (0.02)	174	0.21 (0.03)	522	0.17 (0.01)
Land acquired through renting, borrowing & purchases per AE	291	0.71 (0.06)	291	0.54 (0.06)	291	0.68 (0.08)	873	0.64 (0.04)
Real annual earnings aggregated at a household level/10000 (Ug.shs)	304	64.02 (5.60)	304	92.05 (7.69)	304	89.61 (7.28)	912	81.89 (4.01)
Value of predicted human capital at household level/10000 (Ug.shs)	304	33.33 (1.20)	304	39.80 (1.58)	304	48.62 (2.11)	912	40.58 (0.98)
Value of human capital per adult-equivalent/10000 (Ug.shs)	304	4.47 (0.09)	304	6.77 (0.16)	304	7.93 (0.19)	912	6.39 (0.10)
Number of children below 10 years of age	298	2.65 (0.11)	298	2.48 (0.11)	298	2.38 (0.11)	894	2.51 (0.06)
Adult equivalent of children below 10 yrs of age	298	1.50 (0.06)	298	1.53 (0.07)	298	1.56 (0.07)	894	1.53 (0.04)
Tropical livestock units per adult-Equivalent (TLUs)	303	0.29 (0.02)	303	0.22 (0.02)	303	0.25 (0.02)	909	0.25 (0.01)
Livestock asset value per adult-Equivalent /10000 (Ug.shs)	303	9.25 (0.79)	303	8.27 (0.92)	303	9.11 (0.90)	909	8.88 (0.50)
Value of productive equipments per adult-equivalent/10000 (Ug.shs)	304	1.80 (0.13)	304	1.84 (0.17)	304	1.89 (0.17)	912	1.84 (0.09)
Value of livestock and productive farm equipments per adult-equivalent /10000	304	11.03 (0.83)	304	10.09 (1.00)	304	10.97 (0.98)	912	10.69 (0.54)

Notes: (i) Standard errors are parentheses;
(ii) Asset values, income and expenditure per adult-equivalent in real values at 2005 price levels;
(iii) Livestock and TLU[16] equivalent are cows = 0.5, ox = 0.5, sheep = 0.10, goats = 0.10, pigs = 0.20, donkeys = 0.5, chicken birds = 0.01, other birds (turkey, ducks and pigeons) = 0.03, and rabbits = 0.20;
(iv) Productive farm equipments include: plough-sets, horse/donkey carts, wheelbarrows, boreholes, spray pumps, brewing trough, distilling equipment, fish nets, diesel pumps, water tanks, beehives, trailers, grinders, axe, pangas, slathers, hand hoes, spades, storage facility, water tanks, bicycle, and radio.

Land owned is on average slightly lower than land operated. It appears that rural households utilize land markets to adjusting land-labor ratios that is necessary for efficiency of agricultural

[16] We computed Tropical Livestock Unit (TLU) equivalent for livestock species based on FAO weights for sub-Saharan Africa (See Jahnke (1982); the Compendium of Agricultural-Environmental indicators 1989-91 to 2000, Statistics Division, FAO, November, 2003).

production. Table 1 further show that land is a very scarce productive asset in rural areas of Uganda. More than half (56.3%) rural households participated in land renting and borrowing in at least one of the three periods from 2001 to 2005. This is likely to be the case considering that the population of Uganda increased from 23.3 million in 2001 to 27.6 millions in 2006 (UBOS 2009). The population has continued to grow and is currently projected to be 30.7 millions. This study also valued the human capital stock of households using the Mincerian earning function on the annual earnings of individual adult household members (Mincer 1974; Krueger & Lindahl 2001).

The Mincerian earning function specifies a linear relationship between the logarithm of earnings for individuals and the years of schooling, with the slope of this relationship interpreted as the rate of return to investment in schooling. Human capital is in this thesis defined as the value of household investment in education and experience that is acquired from the on-job training and access to health services. Table1 shows that the real annual earnings of households increased from approx. Ug.shs 640,000 in 2001 to 896,000 in 2005. Yet, the value of human capital increased on average from Ug.shs 333, 000 to Ug.shs 486,000 in the same period. The overall average number of young children that were below ten years of age is noted to be 2.51, which translates to 1.53 adult-equivalents. In the case of livestock, the average tropical livestock units (TLU) reduced from 0.29 in 2001 to 0.25 in 2005. During the same period, the value of livestock reduced slightly from approx. Ug.shs 93,000 to 91,000, the value of farm equipments increased slightly from Ug.shs 18,000 to 19,000, while a combined value of livestock and farm equipments decreased slightly from Ug.shs 110,300 to 109,700. These descriptive statistics suggest that the increase in household income to a large extent can be attributed to the accumulation of human capital. And while returns to other productive asset endowments may be high, this seems to have generated limited contributions to the build up of such assets across rural households.

4. Econometric Methods Employed and Challenges

Most noted studies in Uganda and other developing countries that have assessed the impact of asset accumulation on household welfare employed non-experimental identification methods. This is largely attributed to the lack of clean quasi-experiments and randomized trials that can effectively identify causality in social systems where endogeneity tends to be pervasive. This thesis employs several panel econometric methods that give robust parameters after controlling for the effects of time-invariant and time-varying unobserved heterogeneity in estimating

equations of interest. The bias related to endogeneity and sample selection is largely created by the failure to account for the time-invariant unobserved heterogeneity in the primary equation (Vella & Verbeek 1999). Heterogeneity that is time-invariant can be eliminated with fixed-effects estimation. It can also be derived from the reduced form residuals and included in the primary poverty impact equation as an additional explanatory variable. However, there can be another type of endogeneity that contains a time-varying component, and it is this time-varying omitted variable bias that may not be eliminated via fixed-effects style transformations. This can also be attributed to problems of simultaneity (reverse causality), time-varying omitted variable causation, measurement error or sample selection bias (Fernandez-Val & Vella 2007). Econometric methods therefore, need to account for both unobservable time-invariant and time-varying heterogeneity.

This was conducted using the standard Instrumental Variable and the control function models based on the linear combination of strong instruments to predict the endogenous asset variable. Sensitivity analysis based on the alternative assumptions was also employed to ensure that estimates of the first-difference and the residual component models were to a limited extent affected by the spurious correlations related to the time-varying heterogeneity. In the case of a two-stage estimation involving a non-linear model, the standard errors should be bias-adjusted using a bootstrapping procedure, in order to give efficient and consistent estimates. But, when it comes to fitting marginal effects with variables that have a limited distribution of observations functional form concerns should be less central(Angrist & Pischke 2010).

Recent evidence shows that nonlinear models may not be different from linear models such as the OLS and panel FE model when it comes to fitting marginal effects. Angrist and Pischke (2009, p.107 and p.197-198; 2010, p.11-12) argue that while nonlinear models can fit the conditional expectation functions (CEF) of models with limited dependent variables (LDV) better than is the case with linear model, there is very small difference between the two models when it comes to fitting the marginal effects as indicated below:

> "Many econometric text books argue that, while OLS is fine for the continuous dependent variables, when the outcome of interest is a limited dependent variable (LDV), linear regression models are inappropriate and nonlinear models such as probit and Tobit are preffered. In contrast, our view of regression as inheriting its legitimacy from the CEF makes the LDVness less central" Angrist and Pischke (2009, p.94)

It is therefore plausible that the limited dependency characteristic of the regressor may not bias estimates of a linear model, given that the legitimacy of any regression is derived from the CEF that provides the best linear approximation. Notice, the CEF is defined as the expectation of the dependent variable with a given vector of covariates held fixed.

Sensitivity analysis (robustness checks) is also considered to be indispensable when it comes to ascertaining the reliability and the credibility of the model estimates. This is relevant when there are changes in the sample, additional controls are added, the specification of the model varies, or when serious trade-off in the efficiency of specific model parameters is anticipated as suggested below.

> "So what's an applied guy to do? One answer, as always is to check the robustness of your findings using alternative identifying assumptions. That means that you would like to find broadly similar results using plausible alternative models" (Angrist and Pischke 2009, p.245).

Angrist and Pischke (2009, p.245-246) further reiterate the importance of conducting sensitivity analysis with and without controls and the use of better research design, in order to produce stable and credible econometric estimates. In this thesis, in the spirit of Angrist and Pischke, sensitivity analysis of the main estimation methods is conducted using alternative methods. The causal effects of interest are then seen to be bounded by estimates of more than one estimation method, when it is not obvious which of the methods is the most appropriate as this relies on assumptions that cannot be verified with certainty.

This thesis takes care of the methodological difficulties in making unbiased estimates of welfare effects of land, human capital, livestock, children and other productive asset endowments. These asset endowments were tested and found to be endogenous to the household consumption decisions, and are therefore correlated with unobservable household, farm and community characteristics in many contexts. The econometric models employed include: the standard instrumental (IV) approach, the two-step control function (CF) approach, the residual component (RC) method, the first-differencing method (FD), and the generalized additive semiparametric (GAM) model. In combination these methods were able to provide more robust poverty impact estimates of access to additional productive assets than would have been possible by relying on only one of the methods.

The standard instrumental Variable (IV) method

The instrumental variable (IV) approach is one of the three types of econometric methods that feature prominently in quasi-experimental studies that rely on observational data (Angrist & Pischke 2010). The standard IV approach is able to produce consistent estimators, even when there is a problem of endogeneity due to omitted-variable bias, selection bias and measurement errors in the variables of interest. However, this depends on the validity and strength of the instrument(s) for the endogenous variable. The instrument(s) must be highly correlated with the endogenous variable, but uncorrelated with the error term in the outcome equation. The IV estimator may, however, not be an unbiased estimator, given its likely substantial bias in small samples (Baum 2006), and when instruments are weak or correlated with the outcome. The estimates of the two stage-least squares, though consistent, are shown to be less efficient in case of the limited dependent variables, but are robust to heteroscedasticity (Roodman & Morduch 2009).

Whenever there is failure of the instrumentation strategy the estimated coefficients become biased and can lead to erroneous policy recommendations. This concern has prompted recent studies to demand standards on the quality of the natural experiments and on claims made from non-experimental identification methods (Roodman & Morduch 2009). It is therefore important that the selected instruments for each endogenous explanatory variable are first subjected to the well-developed tests of instrumentation including tests for individual and joint significance, test for endogeneity and tests for over-identification. The instruments should be time-varying in order to produce estimates that are more stable and consistent. In this thesis, we make use of a number of instruments that were shown to be strong to predict each of the endogenous land access variables. The IV estimator for the 2SLS, G2SLS panel RE model and the limited-information maximum likelihood (LIML) estimation were employed to provide results that are consistent and comparable.

A two-step control function (CF) approach

A two-step control function (CF) approach is a computationally attractive and a good alternative to the instrumental variable 2SLS approach, but the two estimation methods have the same kind of identification conditions (Wooldridge 2007). It is able to simultaneously test for the endogeneity of a specific regressor of interest and to control for the underlying endogeneity of the explanatory variable in the primary equation. Its ability to produce gains in efficiency of estimated parameters has made the CF more appealing as shown by recent studies

(Wooldridge 2007; Papke & Wooldridge 2008; Ricker-Gilbert & Jayne 2009; Wooldridge 2009). The CF method assumes strict exogeneity of independent variables that also includes a valid instrument conditional on the unobserved heterogeneity. Household specific heterogeneity was modeled using the CF approach in a combination with the Mundlak-Chamberlain device to unobserved effects (Mundlak 1978; Chamberlain 1980; Chamberlain 1982; Chamberlain 1984; Rivers & Vuong 1988; Wooldridge 2007). In our case residuals are computed from the first stage reduced equations on asset endowments and then included in the primary poverty impact equations to test and control for potential biases due to endogeneity of the asset endowment.

The inclusion of the squared residual variable in the primary equation acts as a control for potential biases due to problems of the functional forms. Vella and Verbeek (1999) and Fernandez-Val and Vella (2007) are some of the studies that employed a similar CF approach. In particular, Vella and Verbeek (1999) present some two-step estimators for a wide range of parametric panel data models with censored endogenous variables and sample selection bias by deriving estimates of the unobserved heterogeneity that is responsible for endogeneity or selection bias. The estimates were then included as additional explanatory variables in the primary equation. Fernandez-Val and Vella (2007) also introduced bias-corrected estimators for nonlinear panel data models with both time-invariant and time-varying heterogeneity, using a reduced form by fixed effects procedure to obtain estimates of time-variant heterogeneity underlying the endogeneity or selection bias. A control function was constructed from the reduced form estimates and then employed as an additional explanatory variable. The fixed-effects approach in the second step controls for the time-invariant heterogeneity while the control function is able to account for the time-varying heterogeneity, given that time-varying instruments can be identified.

The Residual Component (RC) approach

The Residual Component (RC) method is a two-step procedure based on Holden et al. (2009) and gives robust estimates in absence of strong instruments to predict the endogenous variable. The method is easy to compute, and employs the first stage residual component asset variable (= Asset variable - predicted asset variable) from a household fixed effects model to test the impact of the asset variable of interest on the second stage poverty variable (household expenditure per adult-equivalent). The RC method requires limited presence of the time-varying unobserved heterogeneity that may be correlated with the residual component asset

variable and the outcome variable. RC relies on non-linearities for identification but may be combined with time-varying instruments if available in the first-stage estimation of the endogenous variable. The method aims to construct a residual that is not contaminated by bias due to selection or endogeneity. Household fixed effects ensure that the residual is uncorrelated with unobserved heterogeneity that is not time-varying. Time-varying instruments may ensure the same for time-varying unobserved heterogeneity. The residual may then be seen as random asset variation that is not contaminated by endogeneity or selection bias (Holden et al. 2009; Holden et al. 2011).

The predicted endogenous asset variable and residual[17] component asset variable (= Asset variable - predicted asset variable) from the reduced equations are then employed as additional regressors in the primary poverty impact equation, which is also estimated with individual household fixed effects (two-stage fixed effects). The impact of the endogenous variable is assessed from the estimates on the residual asset component variable, while the predicted endogenous asset variable serves as an additional control for the unobserved heterogeneity. The RC approach assumes that time varying unobservable heterogeneity is trivial enough to affect the estimates or is controlled for by other included time-varying instruments. The standard errors of the estimated RC parameters were bias adjusted using a bootstrapping procedure up to 400 replications by re-sampling households.

The first-differencing (FD) method

The FD method provides robust (reliable) results, given its ability to eliminate the effects of the spurious correlations due to time-constant unobserved heterogeneity. It does not rely on the use of an instrumentation strategy, given that it is able to difference out the positive first-order serial correlation in residuals. It has an advantage of eliminating unobserved fixed factors that are often a source of omitted variable bias. When the FD model has factors that take long to

[17] Here, the key difference between the RC method and the control function (CF) method is that in the case of the CF method, the residuals derived from the reduced equation of the specified productive asset say land, would be included in the second-step estimation of poverty impact equation to not only test for endogeneity of land access variable, but also to control for the effects of time-varying unobserved heterogeneity. Unlike the RC method, the CF approach relies on the use of strong and valid instruments in the fist-stage to predict the endogenous regressor. It is also the actual productive asset variable (say land) in the second-stage equation of the CF method that would serve as the poverty impact assessment test of interest and also as a control for the limited effects of time-varying unobserved heterogeneity (Fernandez-Val and Vella 2007, Papke and Wooldridge 2008, Ricker-Gilbert and Jayne 2009, Rivers and Vuong 1988, Vella 1993, Vella and Verbeek 1999). The econometric approach is however, different when it comes to RC estimation. In this case, the RC method relies on the residual component land access variable from the first-stage as the test variable of interest in the second-stage estimation.

change, they may turn out to have insignificant or unstable estimates. The FD model relies on weaker exogeneity assumptions that ensure that the first-differenced residuals and explanatory variables are not correlated. This allows control for time-invariant heterogeneity and can provide consistent estimators, implying limited effects of potential superfluous correlations.

The semiparametric generalized additive GAM model

The generalized additive semiparametric (GAM) model is able to produce an adequate statistical fit of the smoothed terms over the data space that controls for the effects of potential nonlinearities and endogeneity of asset variables. The GAM model assumes that observations for the dependent and explanatory variables are independently and identically distributed (i.i.d), but some level of conditionally heteroskedastic error process of unknown form can also be allowed (Li & Racine 2006). The model is able to obtain consistent parametric estimates and estimators of the unknown smooth functions using the smoothing technique that takes variable shapes depending on the data space that in turn can limit the bias due to endogeneity of the key explanatory variables (Carter & May 1999). The semiparametric estimation has the advantage of producing reliable estimates based on the adequately smoothed statistical fit that also controls for potential non-linearities of asset variables in the same model. The thesis therefore provides robust assessments on how access to productive assets impacts on household welfare in rural Uganda, and the findings are expected to make a contribution in the literature on asset poverty and poverty reduction among the rural households.

5. The Structure of the Thesis

This section presents a summary of the five papers that constitute this dissertation and their contribution to challenges of sustainable development in rural Uganda. The papers correspond to different main objectives and research questions of the thesis. For each of the papers, I highlight the specific objectives, methods employed and major findings. The overall discussion and conclusion of the dissertation are presented at the end of this section. Figure 3 (above) shows the linkages between each of the four papers in this thesis and different aspirations of sustainable development that include social progress, economic development and ecological integrity. Each of the papers makes a methodological and empirical contribution to the literature of poverty alleviation and economic development that fits into a wider framework of sustainable development.

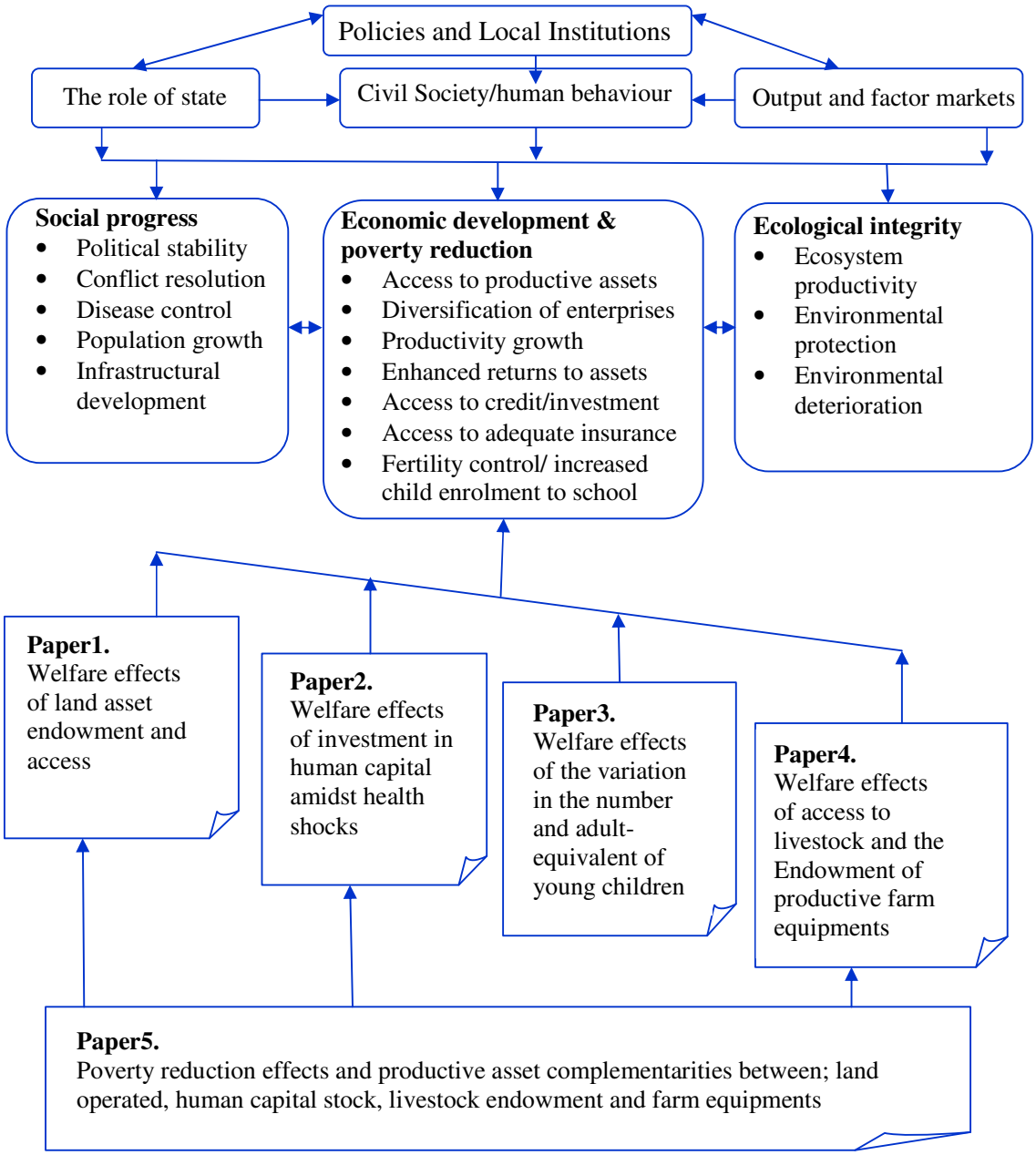


Figure 3 Overview of the structure of papers in this dissertation

Paper 1
Modes of Land Access and Welfare Impacts in Uganda

This paper estimates the poverty reducing impact of land access through market and non-market avenues on household welfare in rural Uganda. The research questions are whether an increase in land access can generate significant welfare-effects to rural households, and whether the marginal poverty reduction effects of land are significantly different for different modes of land access. Land sales and land rental markets may enable land transfers from less

able to more efficient producers, and specifically, land rental markets can provide affordable means of land access to the poor. There are also concerns that land markets may create land concentration in the hands of few inefficient farm households, which may compromise the poverty reducing effects of land. In this paper, we hypothesize that the poverty reducing effect of land can be substantial when more poor but efficient farm households are able to acquire additional land.

Regional imbalance in population density and varying migration patterns may have triggered the emergence and evolution of land rental and sales markets in Uganda (Holden et al. 2008b). Land markets are reported to be widespread and active in virtually all parts of the country with varying levels of strength (Deininger & Mpuga 2008), but there are few robust studies on welfare effects of land access and on how rental and sales markets influence patterns of poverty in rural Uganda. Previous studies that attempted to estimate the welfare effects of land did not control for endogeneity of land access and unobserved heterogeneity. And while a recent study by Holden et al. (2008) provides evidence on access to land through the market in several countries of Africa including Uganda, they did not study the welfare effects of land access through different means including through the market. Pender et al.(2004) indicate that improvement in access to land and other assets including education can be important in breaking the downward cycle of poverty and land degradation. This study therefore makes a novel contribution by providing robust evidence on the impact of land access through market and non-market avenues on household welfare measured in form of expenditure per adult-equivalent.

Using balanced panel data for 309 households in three periods, we employed the Residual Component (RC) method based on Holden et al. (2009) as the preferred econometric method. The alternative standard Instrumental Variable (IV) method was employed as a robustness check for the key results. These methods are easy to compute and allow us to control for problems of unobservable household heterogeneity and endogeneity of household land access. We found significant poverty reduction effects of increased land access in form of owned, operated and market-accessed land after controlling for endogeneity of land access and for the effects of the unobserved heterogeneity on household welfare. Whether accessed through the market or non-market ways, land is found to have significant poverty reducing effects in rural Uganda. The other significant finding was that better land access through the market has

stronger welfare-improving effect than better land access through inheritance. This is likely to be the case because land markets to a larger extent transfer land to more efficient producers.

Paper 2
Changes in Human Capital and Impact on Household Welfare in Uganda

This article employs the income based approach to compute the value of household human capital. It then estimates the poverty reducing effects of changes in the human capital in the wake of idiosyncratic human capital shocks. Specifically, this study assesses: (i) the extent to which changes in human capital impact on real household consumption expenditure per adult equivalent and, (ii) whether the variation in the health shocks to human capital in terms of death incidences and sick days have a significant impact on household welfare. People invest in education in order to enhance welfare and livelihood choices (Schultz 1961; Le et al. 2003). This perception notwithstanding, the existing evidence on the impact of education on the welfare of agricultural households especially in developing countries is mixed. Still, the average returns to investment in schooling in Sub-Saharan Africa (SSA) including Uganda, are reported to be one of the highest in the world (Psacharopoulos & Patrinos 2002). Yet, despite these high returns, a substantial number of households in SSA remain in poverty, even when they have invested in education (Appleton 2001). This has created controversy and the need to clearly understand the usefulness of education in improving the welfare of the poor agricultural households.

In the case of Uganda, some studies have examined the impact of education attainment on household productivity and welfare (Bigsten & Kayizzi-Mugerwa 1995; Appleton & Balihuta 1996; Appleton 2001; Deininger & Okidi 2003). All these studies employed econometric methods that assumed education to be exogenous to household decisions and this may have biased their findings. And while most studies in developing countries that have investigated the poverty reduction effects of access to human capital face challenges of establishing causality, they also tend to depend on small samples and weak econometric methods that in turn produce anecdotal evidence. This paper therefore, makes a systematic analysis of household investment decisions in human capital across rural households using a unique household panel data set surveyed in 2001, 2003 and 2005, and a two-step control function (CF) approach in combination with Mundlak-Chamberlain device to control for unobserved effects in order to generate unbiased estimates.

The main finding of the analysis is that increased access to human capital through investment in education and on-job training of household members has strong and highly significant poverty reducing effects. Rural households with more educated and skillful members are shown to gain higher welfare improving effects after we have controlled for endogeneity of human capital gain and losses. There has been a considerable improvement of the human capital of the households from 2001 to 2005 and this account for a large share of the poverty reduction in this period. The low levels of human capital have therefore made investment in education an imperative poverty reducing instrument, but the incidence of idiosyncratic health shocks to human capital in terms of deaths and sicknesses within households appeared not to have significant effects on consumption expenditure per adult equivalent, implying that households have been able to protect themselves from the devastating effects of such idiosyncratic shocks through consumption smoothing.

Paper 3
Children and Household Welfare: Evidence from Rural Uganda

This paper assesses the role of children as an investment good to their families in rural Uganda, given the newly introduced universal primary and secondary education in the country. The analysis estimates the impact of young children on household welfare in rural Uganda. Specifically, the article measures the impact of the variation in the number and adult-equivalent of young children below ten years of age on household welfare. It also examines the distribution of the endowment of children across households of different welfare levels, and how this endowment interacts with the adult human capital to influence household welfare.

Children can generate immediate benefits either in form of income or otherwise when they engage in useful productive activities on the farm, in small businesses or assisting in domestic activities. Children can also contribute to the human capital accumulation of the household in the medium and long term, and can play a crucial role in the retirement planning of their parents (Cigno et al. 2002; Scholz & Seshadri 2007). The benefits of having children are however, balanced against the cost of child-rearing in terms of parental expenditure on food, clothing, schooling, and other requirements. These costs suggest a negative impact on the household per capita growth in consumption (Becker & Barro 1986), and may encourage families to have few children. In order to minimise part of this cost and also to reduce child labour, the government of Uganda introduced free education to every child in 1997. More farm households in rural areas are now able to send their children to school. These are two

conflicting arguments on the welfare implications of children across households, yet empirical evidence on how young children influence poverty levels in developing countries is still limited. The question is whether the on-going universal primary education (UPE) program has affected short term benefits that rural households derive from their young children?

The article uses the same household panel data from 2001, 2003 and 2005, and employs non-parametric smoothing techniques of locally weighted regression, and the first-differencing (FD) method as the preferred estimation approach, while the residual component (RC) method based on Holden et al. (2009) was employed as the robustness check. The two panel econometric methods were used to control for the unobserved household heterogeneity and endogeneity of young children and give unbiased poverty impact estimates.

The analysis found small negative and significant poverty impact of increased number and adult-equivalent of young children, which becomes insignificant after controlling for both the potential trade-offs between investment in human capital embodied in adult household members, and the differences in child endowments across households. This suggests limited short-term economic benefits of children and a strong trade-off between household investment in adult human capital and in the endowment of children. Households with more endowment of young children are shown to gain insignificant short-term welfare effects. This can be explained by the improved access to education and the reduced cost of child education through the on-going universal primary education in Uganda.

Paper 4
Welfare Impacts of Access to Livestock Holdings and the Endowment of Productive Farm Equipments in Rural Uganda

This article assesses the impact of accumulating additional real value of productive farm equipments (in Uganda shillings (Ug.shs) and more holdings of the livestock endowment (in terms of tropical livestock units and the corresponding real livestock value) on real household expenditure per adult-equivalent (Ug.shs). It also evaluates the inequality level and differences in the distribution of the two endowments across households of varying welfare levels. While production and consumption of livestock and livestock products has been growing rapidly to the extent of creating a livestock revolution in Uganda and the rest of the ECA region (Delgado et al. 1999; Kristjanson et al. 2004; Pica-Ciamarra 2005; Omamo et al. 2006), a substantial proportion of rural farm households remain in poverty. These high growth rates have been

attributed to the increase in population, growth in GDP per capita, and urbanization that may have boosted demand for food of animal origin (Omamo et al. 2006). These high growth rates in demand for livestock products are expected to create opportunities for livestock sector development. The question is to what extent the variation in the endowment of livestock and farm equipments contribute to household consumption expenditure in rural Uganda.

The analysis utilizes the residual component (RC) approach based on (Holden et al. 2009) as the preferred method, and the first-differencing (FD) method as the robustness check of key results. The two methods are used to control for the endogeneity of access to productive assets and correlations due to time-invariant unobserved household heterogeneity. Statistical differences in the distribution of livestock holdings and productive farm equipments across households in different welfare levels (quartiles of expenditure per adult-equivalent) were tested using the first-order stochastic dominance analysis. The Gini coefficient was employed as a measure of the statistical dispersion to highlight the underlying inequality in levels of household productive asset endowments in rural Uganda.

The study reveals that there are low levels of productive asset endowments in rural Uganda. And while this has made access to livestock and farm equipments important determinants of poverty reduction, inequality in access to these assets is also noted to be high. Also found is a clear positive correlation between household welfare and access to additional productive asset endowments. The endowments of livestock and farm equipments were found to be statistically lower for poor farm households in the lower quartiles of expenditure per adult-equivalent compared to farm households in higher quartiles of expenditure per adult-equivalent. The major finding of this study indicate significant welfare increasing effects of access to additional livestock holdings and the endowments of productive farm equipments after controlling for the endogeneity of each of the asset endowment and the unobserved heterogeneity.

Paper 5
Productive Asset Complementarities and Impact on Rural Poverty in Uganda

This final paper employs a translog production function with four assets; land operated (acres), adult human capital in Uganda shillings (Ug.shs), livestock endowment (Ug.shs), and physical farm equipments (Ug.shs) to assess whether there are significant interactions (synergies) that characterize assets as complements or just substitutes (facilitating specialization) in household income generation in rural Uganda. The study estimates the relative poverty reduction impacts

of accumulation of these productive assets and also the asset interaction effects. This is also to control whether the earlier four papers lost something when assessing one asset category at the time. The endowment of young children was left out of this analysis, given that evidence (see findings of paper 3) showed that having more young children in a household generates small and insignificant short-term welfare effects.

Asset poverty can create low social welfare, and compared to urban areas, higher and persistent poverty levels in rural areas of Uganda raises considerable questions as to whether households can substantially benefit from their productive asset endowments to successfully get out of poverty through asset accumulation. This paper investigates the joint contribution of four productive asset endowments to welfare improvement of households in rural Uganda by testing for alternative functional forms and possible asset interaction effects. A parametric first-differencing (FD) model together with Cobb-Douglas and translog production function analysis were employed to generate consistent estimates using the same household panel data that was collected in 2001, 2003 and 2005. An alternative, a semi-parametric statistical smoothing method was also estimated as the robustness check. These different methods were used to control for the potential interactions in the estimates of poverty reduction effects of different assets. Poverty was measured as consumption expenditure normalized to the poverty line, while each asset endowment was normalized to sample mean endowment.

The findings of this study show that household access to all four assets; operated land, human capital; livestock endowments; and physical farm equipments in rural Uganda have strong and significant poverty reduction effects. Additional units of operated land, human capital, livestock, and productive farm equipments were found to reduce poverty in rural Uganda. The relative marginal poverty reduction impacts were significantly higher for human capital than for farm equipments, livestock, and operated land. Only weak indications of significant asset interactions and deviations from log-linear asset-welfare relationships were found. The evidence on interaction effects was therefore not robust to alternative specifications, while the effects of each asset category were robust and highly significant. This strengthens the confidence in the findings in each of the four papers that studied one asset endowment at the time. The findings of this study suggest that accumulation of productive assets is a good instrument for poverty reduction in rural areas. Increasing land scarcity may limit the opportunities for land accumulation in densely populated areas and cause a need to invest more in human capital as a poverty reduction strategy.

5.1 A summary of the estimated welfare effects for different productive assets

Table 2 (below) presents a summary of the estimated welfare effects for each of the productive assets and health shocks in rural Uganda. The welfare effects are derived from all the main estimation models and their respective robustness checks presented in each paper of this thesis.

Table 2. Welfare Effects/Marginal effects of access to Productive Assets in Rural Uganda.

	Household expenditure per adult-equivalent/10000 (Ug.shs)		
	Actual (untransformed)	Log transformed	
Log (or actual) productive asset	Papers 1&4	Papers 2& 3	Paper 5##
endowment	1	2	3
Actual (& log) per adult-equivalent land access (acres)			
Land owned	8.19** - 12.92*	-	-
Land operated ++	7.83** - 14.02*	-	0.22**
Land inherited	5.66*** - 6.39***	-	-
Land access through the market **+++**	10.45*** -21.01**	-	-
Log human capital			
Log human capital per adult-equivalent/10000 (Ug.shs)	-	0.41*** - 0.43***	0.74*** - 0.77***
Idiosyncratic health shocks to human capital			
Log sick-days per adult-equivalent	-	0.07	-
Log actual number of sick-days	-	0.02	-
Dummy variable for death incidence	-	-0.12 - -0.06	-
Log Child endowment (controlling for the effects of adult human capital)			
Log of number of children< 10 years	-	-0.101 - -0.148**	-
Log of adult-equivalent children<10 years	-	-0.158* - -0.199**	-
Log of number of children<10 years of age per adult-equivalent	-	0.186 - 0.059	-
Log proportion (% adult-equivalent) of children<10 years of age	-	0.140 - -0.024	-
Actual (& log) livestock holdings and productive equipments			
Tropical livestock units(TLUs) per adult-equivalent	24.26***- 25.56***	-	-
Asset value per adult-equivalent /10000 (Ug.shs)			
Value of livestock holdings	0.69*** - 0.75***	-	0.27*** - 0.32***
Value of productive farm equipments	2.71*** - 3.20***	-	0.28*** - 0.33***
Value of livestock holdings and farm equipment	0.54*** - 0.76***	-	-

Notes: **++** Land operated explanatory variable is log transformed in model specification 3, and represents all land access modes in paper 5; **+++**Land access through the market also includes borrowing. The welfare effects are derived from the estimated models for the poverty impact equation presented in different papers of this dissertation; in case of Paper 5##, household welfare was measured as consumption expenditure normalized to the poverty line, while each asset endowment was normalized to the sample mean endowment; * Significant at 10%; ** significant at 5%; *** significant at 1%.

The Table provides a range of the estimated welfare effects (marginal effects) that represent the minimum and the maximum coefficients, with their corresponding levels of statistical significance for each of the productive asset and shock variables. The dependent variable in

each model is the real household expenditure per adult-equivalent, but for paper 5 this is represented by the household expenditure normalized to the real poverty line.

In case of land access (the first rows, Table 2), any additional acquisition of land whether through market or non-market modes is shown to be associated with highly significant and positive impact on household welfare. The coefficients on different modes of land access are positive and significant on expenditure measure of welfare in model specifications 1 and 3, but in terms of magnitude the welfare effects of land are highest for land acquired through the market (rentals, purchase, and borrowing) and lowest for inherited land. This suggests that better land access through the market has stronger welfare improving effects than better land access through non-market means. For example, access to 1 acre of land through land rental and purchase market increases household expenditure by approximately Ug.shs 104,500 - 210,100 (i.e. US$[18] 59-118, or 40-80 % of poverty line income) per adult-equivalent in a year compared to approximately Ug.shs 56,600 - 63,900 (Us$ 32- 36 or 22-24% of poverty line income) per adult-equivalent for additional 1 acre of inherited land. The coefficient of land operated in paper 5 denotes the elasticity, implying a 0.22 percent increase in expenditure per adult-equivalent (normalized to poverty line) for every 1 percent increase in sample mean land operated.

Similarly, investing in human capital is shown to significantly improve household welfare more than is the case with land access. For instance, the coefficient on investment in adult human capita is positive (0.41-0.77) and highly significant at 1 percent. This suggests that for every 1 percent increase in sample mean adult human capital (or absolute adult human capital per adult-equivalent) in a year, the gain in household poverty line expenditure (or expenditure per adult-equivalent) is between 0.41-0.77 percent. The welfare effects of health shocks appear to be insignificant, and this implies that rural households have reliable coping strategies and ability to insure themselves towards the effects of such shocks.

Interestingly, having more children is associated with a negative and significant welfare effect, after controlling for likely trade-off between the number of children and investment in adult human capital in a household. However, this negative welfare effect of children becomes

[18] Using a 2005 average foreign exchange rate of 1,781 Uganda Shillings per United States Dollar (US$- Source: Bank of Uganda website). The poverty line income in Uganda is estimated to be Ug.shs 261,717 per adult-equivalent.

insignificant after controlling for both the trade-off with investment in adult human capital in a household and the differences in the number of children across households (by normalizing child endowment to household adult-equivalent). Thus, an increase in the number of children appears not to generate significant short-term welfare effects to rural households.

Household endowment of livestock in terms of TLUs and value is shown to generate positive and highly significant welfare effects to rural households. For example, one additional TLU generates about Ug.shs 242,600 - 255,600 (US$ 136-144, or 93-98% of poverty line income) that is also equivalent to Ug.shs. 24,260 - 25, 560 increase in household expenditure per adult-equivalent for access to one additional goat (0.1 TLU) in a year. Similarly, for every Ug.shs 10,000 additional increase in the value of livestock holding per adult-equivalent, a household is bound to gain between Ug.shs 6,900 -7,500 in a year. The related marginal effect (in paper 5) suggests that a 1 percent increase in the sample mean value of livestock holding significantly increases household poverty line expenditure per adult-equivalent by 0.27-0.32 percent.

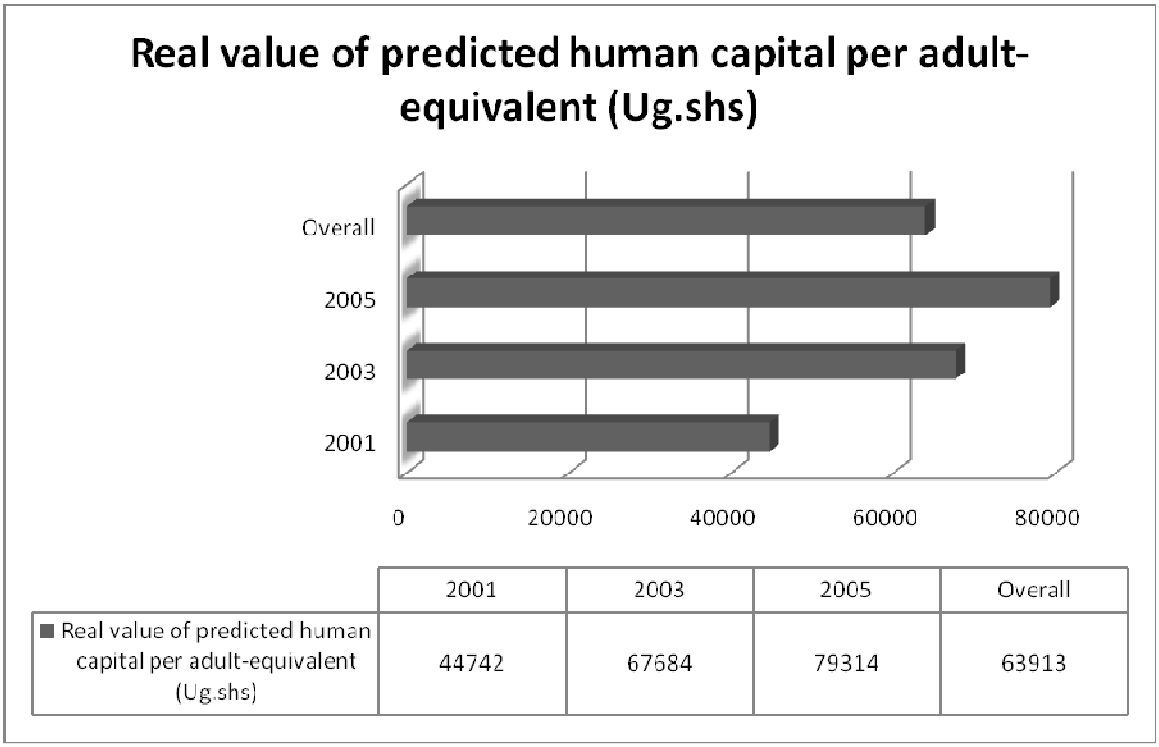
An increase in the investment of farm equipments by Ug.shs 10,000 per adult-equivalent increases household expenditure per adult-equivalent by Ug.shs 27,100 - 32,000. In the case of model specification 3, this is equivalent to a 0.28-0.33 percent increase in poverty line expenditure per adult-equivalent for every 1 percent increase in the sample mean value of physical farm equipments. When a similar investment is made in Ug.shs 10000 value of combined asset of livestock and farm equipments, the gain in household expenditure per adult-equivalent becomes Ug.shs 5,400 - 7,600. These results therefore suggest that the household welfare increases more with access to additional units of: human capital, followed by physical farm equipments, livestock holdings, land access through the market (purchases, rental and borrowing), land access through inheritance, and lastly the endowment of young children that also appear to be insignificant.

6. Overall Conclusion

An increase in population density, land fragmentation, and varying regional migration patterns in the last three decades have created land scarcity in rural Uganda and this has lead to the emergence of land rental and sales markets that are reported to be widespread in virtually all parts of the country, but with varying levels of activity. Our analysis indicates significant poverty reduction effects of increased land access in form of owned land, operated land, and market accessed land. And while better land access through the market has stronger welfare-

improving effect than better land access through inheritance, this is likely to be the case because land markets to a larger extent transfer land to more efficient producers.

The low levels of human capital in rural areas of Uganda have made investment in education and on job-training an imperative poverty reducing instrument. The accumulation of human capital through investment in education and on-job training of household members (see Figure 4, below) enhances the ability of rural households to generate higher income and to smooth consumption overtime.



	2001	2003	2005	Overall
Real value of predicted human capital per adult-equivalent (Ug.shs)	44742	67684	79314	63913

Figure 4 A bar graph indicating growth in adult human capital across households, 2001-2005.

Human capital seems to be the only type of capital that is really growing in per adult equivalent sense and therefore the only one that really appears to be contributing to broad scale poverty reduction in rural Uganda. In addition, households appear to be effective in smoothing the effects of idiosyncratic health shocks to human capital that are in form of unexpected death incidence and prevalence of sicknesses. This can be attributed to the prevailing local institutional arrangements, family networks and other informal insurance mechanisms that seem to be active and strong enough to smooth out the negative effects of such health shocks. These can provide affordable informal insurance to the affected households in time of need for

support to the cost of treatment, funerals and other related incidents. The introduction of the free universal education in the last one and half decades has increased opportunities for every young child to access schooling, and this has in turn lead to small and insignificant short-term welfare effects for having additional number of young children in a household. Contrary to the popular views about short term economic benefits of "child labor", young children in rural Uganda appear to engage in economic activities to a limited extent. Families are increasingly finding it rational to have few children that can be sent to school. The trade-off between household investment in adult human capital and in the endowment of children is also strong. This appears to play a significant role in reducing the negative welfare effects of having a large number of children in rural Uganda.

The low levels of productive asset endowments in rural Uganda have made access to livestock and farm equipments important instruments of poverty reduction. There are significant welfare increasing effects of access to more livestock holdings and additional physical farm equipments and implements. Figures 5 and 6 (below) illustrate the relative shares of the alternative types of productive capital together with their estimated contributions to household consumption in 2001 and 2005.

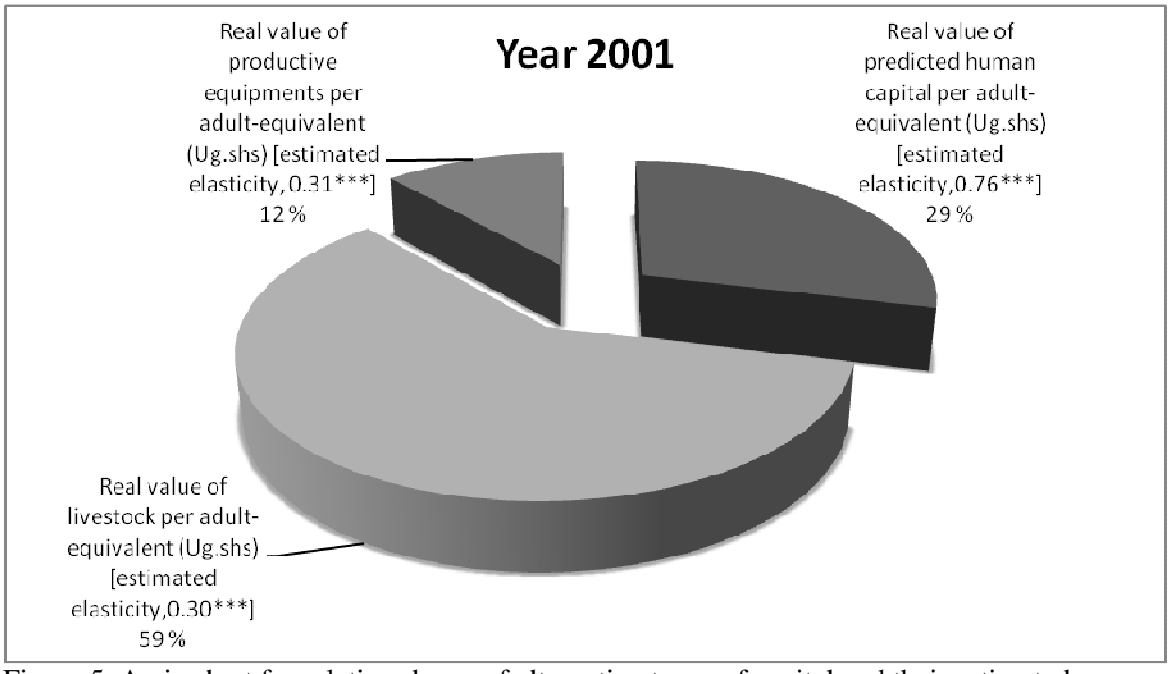


Figure 5 A pie chart for relative shares of alternative types of capital and their estimated contribution to consumption in rural Uganda, in 2001.

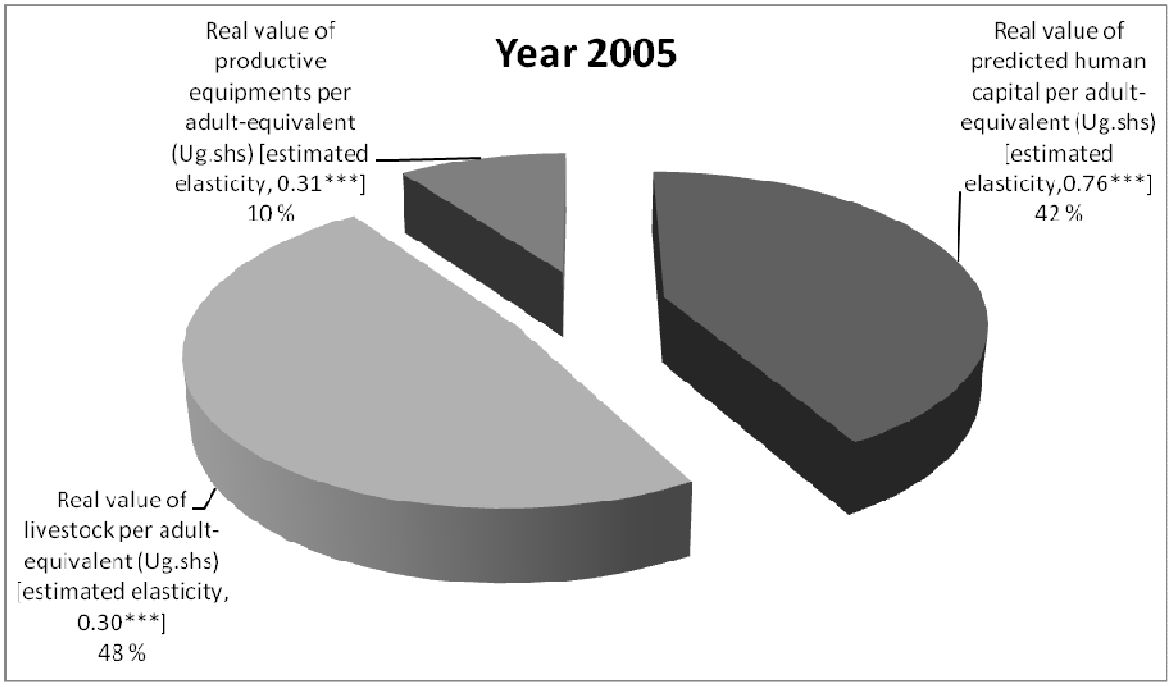


Figure 6 A pie chart for relative shares of alternative types of capital and their estimated contribution to consumption in rural Uganda, in 2005.

The value of land operated per adult-equivalent is not included in the two figures, due to irreconcilable problems (land prices were reported for each parcel and not for a standard unit of land) with information on land prices and rental rates. The share of total endowment per adult-equivalent for livestock and farm equipment appeared not to change significantly between 2001 and 2005. The share of human capital per adult-equivalent on the other hand increased substantially from 29% to 42%, and has the highest (0.76) contribution (elasticity) to household consumption than is the case for land (0.22), livestock (0.30) and farm equipments (0.31).

It is also evident that the rural poor are clearly dominated by richer households when it comes to endowments of productive assets including livestock and farm equipments, and this is exacerbated by high levels of inequality in access to these endowments. Poor households are therefore unable to access sufficient productive assets that are vital for the generation of the much needed incomes, especially in high market access areas.

Increases of all four assets have strong and significant poverty reduction effects. The relative marginal poverty reduction impacts were significantly higher for human capital than for physical farm equipments, livestock holdings, and operated land. Only weak indications of significant asset interactions and deviations from log-linear asset-welfare relationships were

found. "Human capital and livestock", and "livestock and farm equipment" appear to be potential substitutes in the household production process. Household accumulation of productive assets, especially human capital, can be good instruments for poverty reduction in rural areas.

6.1. Overall Policy Implications

There is need for effective policies and interventions that can enhance investment in additional education and on-job training, investment in sufficient physical farm equipments, more livestock holding, and additional land access through the market for efficient agricultural production. The total size of agricultural land can also be expanded by reducing fallow land and putting idle land in different regions of the country to productive use. Families should be encourage and supported to have fewer numbers of children, if rural poverty is to be significantly reduced.

Policy interventions should support market oriented land reforms that can spur economic growth and land use efficiency as the off-farm economy develops. Rural land owners and local opinion leaders need to be sensitized and empowered to: resolve conflicts that may arise on land, and seek certificates of customary land ownership and certificates of land occupancy that can also be converted to either freehold or leasehold land title as indicated in the 1998 Land Act. This can ensure better social control of land to prevent land grabbing, better access to credit and for establishing land rental and sales markets that are more open, competitive and able to effectively transfer land in ways that help the poor to adopt to more productive forms of land use. This requires capacity building and training of members of the village, land tribunals, land committees, district land registry. Furthermore, influential local chiefs and the powerful cultural leaders in every region of the country can be engaged to come up with a culturally acceptable, largely uniform and a legitimate framework of land market operation that is pro-poor and able to cushion the vulnerable groups such widows and orphans.

The functioning of land markets can be enhanced by harmonizing different measurements of land that currently exist in Uganda into a more socially acceptable standard method, establishing uniform land rental contracts and obligations that can foster the terms of land supply and demand based on tangible attributes like land quality. The introduction of acceptable sanctions in case of deliberate default by either party together with well defined compensations when losses are incurred due to violations of initial agreements between

landlords and tenants can: create harmony, reduce the costs of initial entry in the land market, and reduce conflicts and the costs of searching and screening (due to information asymmetry) on both sides of the land market. Introducing a progressive land tax for large land holdings can also serve to mobilize land that is idle (not well utilized) and this can also encourage land-rich households to rent out their land to more efficient producers. Deininger (2005) suggests that unlike taxes levied on consumption, progressive land taxes may not hurt the poor, can discourage speculative land accumulation, support more intensive and effective land use, and may strengthen the accountability and independence of local governments before the public.

The findings of this thesis lend support to the ongoing public investment in human capital development that is reported to have increased enrollment in primary, secondary and vocational schooling. It is important to adopt policies that can further increase returns to education and at the same time reduce the cost of seeking for additional schooling. These may include setting a minimum wage for all working adults and investing in public sectors and private sectors that create employment to semi-skilled and skilled rural people. Other interventions may range from the introduction of programs that provide student loans, subsidies to the disadvantaged households to pursue further training, grants to poor schools, scholarships to poor children and encouraging on-job apprenticeship in the private farm and off-farm enterprises.

Human capital accumulation in rural Uganda can confer a desirable shift to endowments of children that are affordable and vital for enhanced household welfare in the long-term. There is need to adopt policy interventions that can further reduce child labour and elimination of every extreme form of child exploitation, while promoting child education at the same time. These can include educational policies that reduce the marginal cost of school attendance, programs of food and cash transfers for school enrolment, improved technologies that can increase the productivity of adults, health policies that can reduce morbidity and mortality of children, and improvement of social security policies that can further reduce the demand for children as a form of investment.

It is also important to improve the functioning of rural markets by improving transport and marketing infrastructure to reduce costs of transactions, and uncertainty. This can establish a supportive economic environment that encourages trade, asset accumulation and investment in productive enterprises for income generation. Policy intervention that can favor greater attention to access and use of productive assets, enhance productivity growth and returns to

household productive assets are commendable. These can specifically aim at providing affordable veterinary and extension services, strengthening the coping strategies of the rural poor to the effects of unexpected shocks. For example, building valley water dams and irrigation facilities can help minimize the risk of water shortages during drought seasons. Other interventions may provide reliable health services, provide credit services, promote good livestock husbandry, and invest in reliable infrastructure to boost profitable market activities.

6.2. Areas of Further Research

This thesis did not decompose the estimated welfare effects of land access and other productive assets across households of different categories of land endowments and welfare status. We therefore recommend further analysis that can reveal how households of different levels of welfare status might benefit from better access to land and non-land assets in rural areas.

There is need for more empirical evidence on how market related-land reforms and benefits of land transactions can reduce poverty and spur meaningful land related investments in the four regions and different land tenure systems of Uganda. Further research should be done on a vigorous comparison of welfare effects of investment in education for individuals working in different sectors of farm and off-farm employment. This can help to highlight specific levels of human capital that can spur meaningful productivity and returns in the agricultural sector and off-farm self-employment.

There is need for more evidence on the effectiveness of different interventions that can further increase child enrolment to school and eliminate child labor in economic activities. Further research should be done on the impact of fertility levels, child labor allocations, and incentives for school enrollment as derived from programs for cash transfers for schooling, food for education, and free universal education for enrolment of every child need to be examined.

This thesis found insignificant effects of health shocks on rural households. It is therefore important to conduct further investigation on the effects of informal mechanisms that rural households utilize to insure themselves towards the effects of these idiosyncratic health shock.

The contribution of access to additional farm equipments on household welfare was found to be unexpectedly very large and puzzling. This can be explained by the effects of; high risk, under investment in these equipments due to cash constraints, attempts to avoid the

consequences of sharing (envy) in the neighborhood, and the likely time-varying endogeneity bias that could have remained in the estimating models. Still, the high, yet very robust returns to an increase in endowment of heterogeneous farm equipments could not be well understood. Further research should be done on why this is the case.

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Paper I

Modes of Land Access and Welfare Impacts in Uganda

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ABSTRACT. This article estimates the poverty reducing impact of land access in rural Uganda. Using balanced panel data for 309 households in 2001, 2003, and 2005, models that control for unobserved household heterogeneity and endogeneity of land acquisition and disposition are employed to measure the poverty-reduction effect of land on household expenditure per adult equivalent. Significant poverty reduction effects of increased land access in form of owned, operated and market-accessed land were found. The poverty reduction effect for land accessed through the market was significantly larger than the poverty reduction effect of land accessed through inheritance. (JEL Q24, Q15, and O12)

Key words: Endogeneity of land access, unobserved heterogeneity, poverty impacts.

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Modes of Land Access and Welfare Impacts in Uganda

I. INTRODUCTION

Empirical research indicates that land acquired through markets or otherwise may play an important role for rural household welfare (de Janvry et al. 2001; Pender et al. 2004). A recent study shows that access to a small amount of land can permit mobilization of family assets to create large income gains for the poor (Finan et al. 2005). Land markets may enable land transfers from less able to more skilled households, and particularly land rental markets may provide affordable means through which the land-poor can gain access to more land to promote productivity and welfare (Deininger & Feder 1998; de Janvry et al. 2001; Nkonya et al. 2005; Deininger & Mpuga 2008). Conversely, there are concerns that poverty reduction effect of access to land may be compromised by land markets that can foster land concentration, especially in the hands of the rich and inefficient owners at the expense of the land-poor (Otsuka et al. 2007; Holden et al. 2008b). In this context, land-poor households are considered to be vulnerable, since they are inclined to lose their land through distress sales when faced with serious shocks.

In this article, we hypothesize that the poverty reduction effect of land can be large when more efficient farmers are able to acquire additional land. Recent evidence on access to land through the market has been provided for several African countries, including Uganda, by Holden et al. (2008c) in their study of emerging land markets in parts of Africa where land scarcity is getting severe. However, they did not study the welfare effects of land access through different means, including through the market. Therefore, this study makes a novel contribution by providing evidence on the impact of land access through market and non-market avenues on household welfare in form of expenditure per adult-equivalent of rural households in Uganda. We are not aware of any other studies in Africa that have been able to do this while controlling for endogeneity of land access and unobserved household heterogeneity.

Land rental and sales markets are reported to be active and widespread throughout Uganda and seem not to lead to a more unequal land distribution (Deininger & Mpuga 2008). However, there is limited empirical evidence on how rental and sales markets influence patterns of poverty in rural areas. There are also methodological challenges related to making unbiased estimates of welfare effects of land and other endowments due to their endogeneity

and the fact that they may be correlated with unobservable household, farm and community characteristics. There can also be severe difficulties in finding suitable instruments to predict land access, given the requirement that the instruments should be exogenous and uncorrelated with the outcome. Here we apply a new residual component (RC) approach based on Holden et al. (2009) as the preferred estimation method. An alternative standard instrumental variable (IV) method that employs a linear combination of five instruments is also estimated as a robustness check of the key results. These two methods allow us to control for endogeneity and unobservable household heterogeneity in estimating the welfare impacts of land access through a) inheritance, b) a combination of inheritance and other methods of acquisition, and c) through market access and borrowing. Furthermore, the methods allow us to assess whether the welfare effects are significantly different for the different forms of land access, and to measure the marginal poverty reduction effect of land access.

The rest of the paper is outlined as follows. Section II summarizes recent economic policies and land reforms that were adopted in Uganda to alleviate poverty. In Section III, we describe data and welfare indicators. Descriptive statistics, results of the first-order stochastic dominance analysis, and poverty status are presented in Section IV. Section V presents a simple theoretical framework. Section VI indicates the specification of the poverty impact equation and alternative models employed as part of robustness checks. The empirical results follow in Section VII and in appendix A. The paper is concluded in Section VIII.

II. ECONOMIC POLICIES AND RECENT LAND REFORMS IN UGANDA

Poverty eradication is a major national goal for the Ugandan government. It was adopted in 1995 with a long-term goal of reducing the incidence of income poverty to less than 10% by 2017. A recent study on poverty trends and expenditure in Uganda shows that poverty levels[19] dropped from 38.8% in 2003 to 31.1% in 2006, while poverty in rural areas was reported to be 34.2% compared to 13.7% in urban areas (UBOS 2006; Ministry of Finance Planning and Economic Development 2010). Efforts to alleviate persistent poverty in rural areas of Uganda lead to the launching of two closely linked national plans; the "Poverty Eradication Action Plan (PEAP)" and the "Strategic Plan for Modernization of Agriculture (PMA)". The two plans were adopted in 1997 to, among other objectives, increase the ability

[19] In absolute numbers, a total of 8.4 million Ugandans live in poverty, and of these 7.9 (94%) live in rural areas (UBOS, 2006). Appleton, (2001b) indicates that the proportion of Ugandans estimated to be living below the poverty line was 34% in 1999/2000.

of the poor to raise their income, improve agricultural productivity and boost marketed output of the rural poor (Ellis & Bahiigwa 2003). The two plans were incorporated into a five-year National Development Plan in 2010 to guide the country's development program and the transformation of Uganda from a peasant to a modern and prosperous country within the next 30 years.

Land legislation in Uganda started in 1900 with the signing of the Uganda Agreement of 1900 with the British Government, where *mailo* land tenure was created by giving large tracts of land measured in miles to the Kabaka (king) of Buganda Kingdom and his notables. Since then, there have been several legislations including the Busulu (annual dues) and Envujo (levy per acre) Law of 1927, the 1969 Public Land Act, the 1975 Land Reform Decree, and the 1998 Land Act (Hunt 2004). For many decades, land under customary tenure was not legally recognized, while policies to nationalize land created unintended consequences such as land grabbing, unlawful evictions and poor implementation. Rural areas as a result experienced low investment, limited land transactions, limited access to credit and, rampant land conflicts (Deininger 2003). Recent land reforms started with the 1995 Uganda constitution that has provisions to strengthen land rights on customary land, especially rights of the underprivileged groups of women and children.

The 1998 Land Act emphasize resolving historical tenure problems by defining and entrenching land rights of all Ugandans including those on customary land to increase land use efficiency for economic growth (Bosworth 2003). The Act not only sets out procedures to enable holders of customary land to acquire certificates of customary ownership, but also enables tenants by occupancy to acquire certificates of occupancy, and together with land lease-holders to convert their certificates to freehold. These land reforms are expected to reduce inequality in land holding, increase land access through better functioning of land rental and purchase markets and enhance agricultural productivity, especially in areas with shortage of land due to the rapid population growth. Therefore, it is of national interest to study poverty reduction effects of land access, especially among the rural poor.

III. DATA AND WELFARE INDICATORS

This study utilizes a three-period household panel data set collected in 2001, 2003, and 2005 by two research projects. The first survey was conducted in 2001 by the International Food Policy Research Institute (IFPRI), and covered two thirds of Uganda including Southwest,

Central, and Eastern and some areas in Northern Uganda. A stratified sampling procedure was employed based on a classification of Uganda's territory according to the agricultural potential, market access and population density. A total of 450 households in 107 communities were interviewed in 2001. The subsequent two surveys were conducted in 2003 and 2005 as part of the Research on Poverty, Environment, and Agricultural Technologies (REPEAT) project, conducted by the Foundation for Advanced Studies on International Development (FASID).

In these surveys, 3 districts that were part of the earlier IFPRI study areas were dropped due to insecurity in the North and Northeastern parts of Uganda. Instead 94 out of 107 communities that were previously covered by the IFPRI survey in 2001 were selected. Only 333 households, out of the 450 households in the baseline survey of 2001 were included in the 2003 REPEAT survey due to the change in the sampling frame in 2003. In addition, out of the 333 sample of households, 20 households dropped out for various reasons in the 2005 survey, while 4 more households with outliers and conflicting values of land access were also dropped from data analysis. This study is therefore based on balanced panel data of 309 households. Data analysis was conducted on 927 observations from 26 districts that include; Mubende, Luwero, Nakasongola, Masaka, Mukono, Kayunga, Rakai, and Mpigi in the central region, Sironko, Tororo, Bugiri, Iganga, Mayuge, Jinja, Kamuli, Pallisa, Mbale, Busia, and Kumi in the Eastern region and Mbarara, Kabale, Kisoro, Kabarole, Kasese, Bushenyi, and Rukungiri in the western region of Uganda. We expect attrition bias to be too small to affect our results.

Household welfare or poverty level

We computed income per adult-equivalent and expenditure per adult-equivalent as measures of household poverty levels. The outcome of any development policy intervention and its corresponding welfare enhancing effects are absorbed and reflected in the individual household members (Ringein 1996). Therefore, the analysis of poverty can be conducted at the household and individual levels. Household income in a year was computed from the summation of value of home crop production net of the cost of inputs, value of home produced livestock that were consumed, cash income from sale of livestock and livestock products net of livestock production costs, and cash income from seasonal and monthly off-farm activities. Distinctively, household total expenditure was constructed from cash expenditure for consumption and value of consumption of home produced goods. Both

measures of household poverty levels were adjusted to 2005 prices. Problems with the household income data especially in the initial period of 2001 compelled us to use the more reliable expenditure data for the estimation of marginal returns to land access.

Land access includes land endowments in acres that farm households own or operate in their production process. Land owned can be accessed mainly through the modes of inheritance (or in form of gifts) and purchases. Land that farm households operate may include land that is accessed through inheritance and market modes of land access including purchases, renting-in and borrowing. Land acquired through the market is a limited dependent variable (LDV) while land owned and lands operated are continuous variables.

We employ a poverty line[20] that was computed by Yamano et al. (2004) using the 2003 REPEAT data set in Uganda. Yamano et al. (2004) adopted the calorie requirement approach that is based on the previous work of Ravallion & Bidani (1994) and Appleton (2001a). The poverty line consists of the expenditure on food and non-food requirements, and was updated in this study to 2005 prices using the consumer price index to take care of changes in the cost of living. Therefore, we define the food[21] poverty line at Ug.shs 199024.4 (US$90.7) and the national poverty line at Ug.shs 261717.1 (US$118.6) per person per year.

IV. DESCRIPTIVE STATISTICS

Tables 1 and 2 provide descriptive statistics for key variables on land access and poverty indicators across rural households. In particular, Table 1 shows a significant growth in household income between 2001 and 2005. During the same period, a trivial growth in household expenditure is observed from Ug.shs 345,036 in 2001 to Ug.shs 387,653 in 2005. The real annual income of households on average was found to be lower compared to the

[20] Yamano et al. (2004) computed the annual food poverty line to be Ug.shs 171,360 ($90.2) per male adult, which is equivalent to Ug.shs 14,280 (US$7.52) cost of the simplified food basket of about 39 items per month times 12 months. Food requirement was defined based on the costs of obtaining 3,000 kilo calories per day for a male adult in rural Ugandan. Using adult-equivalents that were employed in Appleton 2001, food requirements for different age-gender groups were computed. Households whose total expenditure per adult-equivalent was just at the food poverty line was found to spend about 31.5 percent of total expenditure on non-food items, which translated to about Ug.shs 53,960 (US$28.4). The national poverty line was therefore identified to be at Ug.shs 225320 (US$118.6) per person per year.

[21] The food poverty line represents the cost of obtaining 3,000 kilo calories (food requirement) from the food basket of the poorest 50 percent of the population valued at 2005 prices, per day for a month (30 days) in the REPEAT survey. The value of the 3,000 kilo calories per day was deflated with adult-equivalent to control for age-gender differences in food requirement within households (Yamano et al. 2004).

corresponding real annual consumption expenditure. This difference is more evident in the initial year of 2001 and can be attributed to various practical challenges related to measuring income of the rural agricultural households.

TABLE 1
HOUSEHOLD POVERTY INDICATORS AND LAND ACCESS, 2001-2005

	2001		2003		2005		Overall	
	N	Mean	N	Mean	N	Mean	N	Mean
Per adult-equivalent								
Household income (Ug.shs)	309	213481.10 (17246.66)	309	340229.30 (28717.71)	309	376035.00 (24578.79)	927	309915.10 (14023.04)
Household expenditure (Ug.shs)	309	345035.70 (15033.22)	309	386107.50 (37832.47)	309	387652.80 (20196.59)	927	372932.00 (15145.67)
Land owned (acres)	309	1.04 (0.07)	309	0.98 (0.08)	309	1.24 (0.10)	927	1.09 (0.05)
Gini coefficient of land-owned by district	309	0.46 (0.01)	309	0.44 (0.01)	309	0.47 (0.01)	927	0.45 (0.00)
Land operated (acres)	309	1.12 (0.07)	309	1.05 (0.08)	309	1.31 (0.10)	927	1.16 (0.05)
Gini coefficient of land - operated by district	309	0.43 (0.01)	309	0.41 (0.00)	309	0.45 (0.01)	927	0.43 (0.00)
Land purchased (acres)	269	0.67 (0.06)	269	0.49 (0.07)	269	0.60 (0.08)	807	0.59 (0.04)
Land inherited (acres)	256	0.54 (0.05)	256	0.51 (0.05)	256	0.45 (0.04)	768	0.50 (0.03)
Land sold (acres)	19	0.11 (0.08)	19	0.00 (0.00)	19	0.11 (0.03)	57	0.07 (0.03)
Land bequeathed (acres)	55	0.61 (0.14)	55	0.00 (0.00)	55	0.04 (0.02)	165	0.22 (0.05)
Land acquired through-renting &borrowing	174	0.16 (0.03)	174	0.15 (0.02)	174	0.21 (0.03)	522	0.17 (0.01)
Land rented-out and-borrowed -out (acres)	55	0.02 (0.02)	55	0.03 (0.02)	55	0.28 (0.07)	165	0.11 (0.03)
Land acquired thru renting, borrowing & purchases	291	0.71 (0.06)	291	0.54 (0.06)	291	0.68 (0.08)	873	0.64 (0.04)

Note: (i) Standard errors are in parentheses; (ii) Income and expenditure per adult equivalent in real income (2005 value).

There can be limitations of research instruments that depend on recall information over a long period. Besides, enumerators may fail to effectively probe all income sources of the household during data collection. This creates significant data limitations in form of hidden and undisclosed income. It is widely agreed that consumption is a better measure of lifetime welfare compared to current income (Deaton 1997). Thus, the welfare estimates of land access in this study rely on the more plausible consumption expenditure per adult-equivalent as the measure of household welfare. In the case of land asset, households gained access to more land through the market, on average 0.64 acres per adult-equivalent, compared to 0.50 acres of land per adult-equivalent that was accessed through inheritance. Inequality in land distribution is illustrated by the gini coefficients for land owned and land operated per adult-

equivalent between 2001 and 2005. There is a lower average gini coefficient of 0.43 on land operated per adult-equivalent compared to a gini of 0.45 for land owned in the period 2001-2005. This suggests that land access through the market might be helpful in promoting more equitable land access for agricultural production in rural areas of Uganda. In addition, we see a large increase in land rented-out and borrowed-out per adult-equivalent from 0.03 acres in 2003 to 0.28 acres in 2005. The increase in land rented-out and borrowed-out can be explained by the significant rise in the number of households that participated in the supply side of the land market from 5 in 2001 to 48 in 2005. The variability in the means of land that is accessed through different modes can be attributed to changes in household adult-equivalent (size) and the amount of land acquired or disposed in each period.

A graph (Figure A.1 in the Appendix) of net land rented in versus the order rank of households according to the size of land accessed on the two sides of the rental market indicates that only a small proportion of rural households rent out their land. The flat part of the curve represents nonparticipating households. The high share of non-participation may be due to high transaction costs in the rental market. Potential landlords may be reluctant to rent out their land due to tenure insecurity and high costs of identifying tenants that can manage their land well. However, it is evident that a larger number of households participated on the demand side of land rental market. The average size of land acquired through renting and borrowing (acres) is noted to have increased from 0.16 in 2001 to 0.21 in 2005. This is further confirmed by Figure A.2 in the Appendix that shows a plot of size of owned land versus size of net-land rented for the households in the sample. The graph shows that a substantial number of land-poor households access extra land through the land rental market.

First-Order Stochastic Dominance Analysis

As a first assessment of the distribution of land endowment across households with varying levels of welfare, the first-order stochastic dominance analysis (FOSDA) was conducted. The FOSDA tests for statistical differences in land owned and land operated per adult-equivalent across households in different quartiles of expenditure per adult-equivalent. The FOSDA uses cumulative density functions (CDFs) to test for statistical differences in the distribution of land access for households with varying welfare levels. Graphically, the curve for the CDF of a dominated quartile will be to the left of the CDF for the dominating alternative quartile. This implies that a dominating quartile has a lower cumulative density than a dominated alternative. Figures 1 and 2 show results of the FOSDA for land owned and operated.

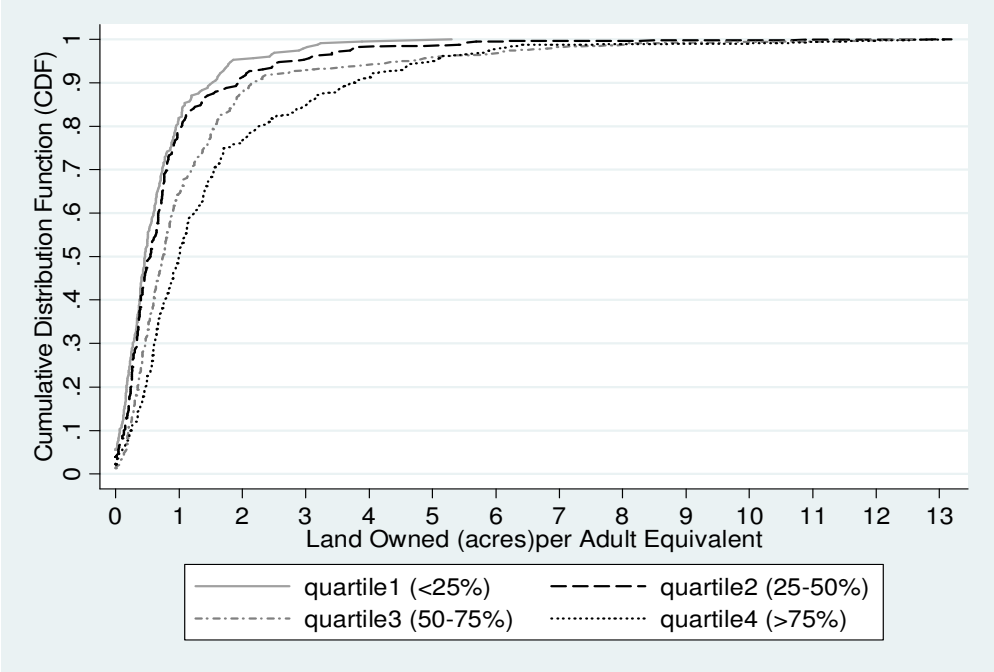

FIGURE1.
FIRST-ORDER STOCHASTIC DOMINANCE GRAPH COMPARING LAND OWNED AND WELFARE LEVELS (QUARTILES) IN TERMS OF HOUSEHOLD EXPENDITURE PER ADULT-EQUIVALENT, 2001-2005

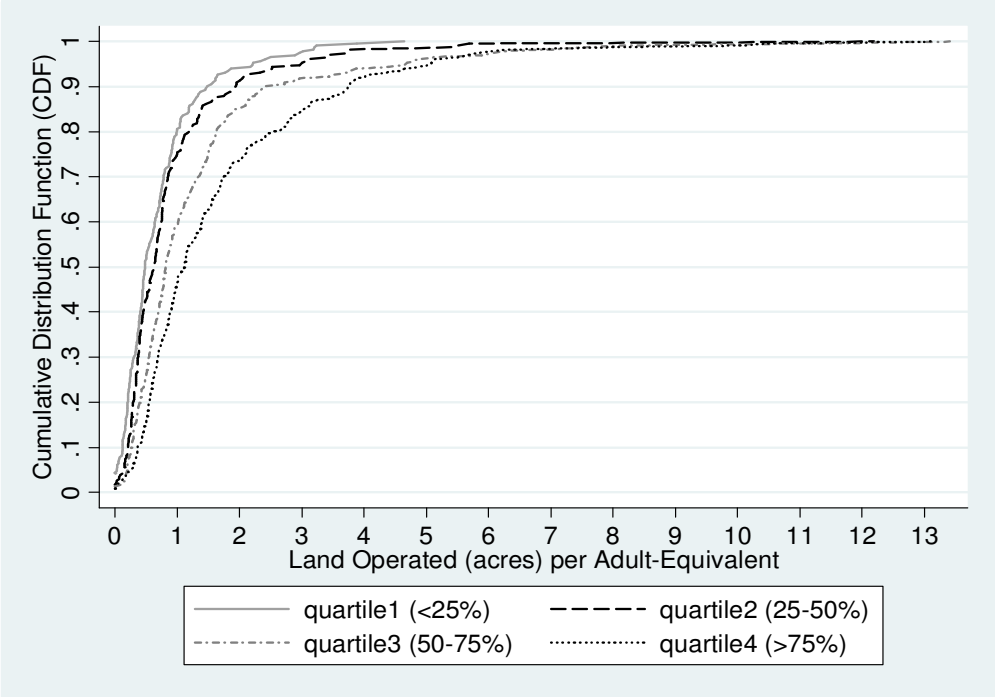

FIGURE2.
FIRST-ORDER STOCHASTIC DOMINANCE GRAPH COMPARING LAND OPERATED AND WELFARE LEVELS (QUARTILES) IN TERMS OF HOUSEHOLD EXPENDITUREPER ADULT-EQUIVALENT, 2001-2005

We see that households in the poorest two quartiles (quartile 1 and 2) are dominated by households in quartiles 3 and 4. The land distribution of households in quartile 4 clearly dominates all other land endowment (owned and operated) distributions in quartiles 1 to 3. Thus, land owned and land operated are statistically highest for households in quartile 4, followed by households in quartile 3, lower for households in quartiles 2 and lowest for households in quartile 1.

Poverty status in rural Uganda

This section indicates a description of poverty levels and poverty dynamics among rural households. Table 2 (below) shows changes in poverty status of households in the sample. Notice that 31% of the households were food poor in 2001, and this reduced to 29% in 2005. Similarly, households that were in general poverty[22] reduced from 52% in 2001 to 43% in 2005.

TABLE 2
HOUSEHOLD POVERTY STATUS BETWEEN 2001 AND 2005

	2001	**2003**	**2005**	**Overall**
Food poverty				
Headcount ratio %	31.07	36.25	29.13	32.15
Poverty gap ratio %	10.90	12.31	8.88	10.70
Sen index *100	14.28	16.66	12.22	14.44
General poverty				
Headcount ratio % (P0)	51.78	48.54	43.04	47.79
Poverty gap ratio % (P1)	18.24	19.26	15.49	17.66
Sen index *100 (Ps)	24.89	25.52	20.61	23.74
Gini coefficient for households below poverty line	0.199	0 .215	0.187	0.202
Change in general poverty status				
Never poor			62	20.1%
Poor in one period (transitory poverty)			101	32.7%
Poor in two periods (transitory poverty)			96	31.1%
Always poor (chronic poor)			50	16.2%
Total number of households			309	100%

Note: A household is defined as food poor if its real expenditure on food per adult equivalent is less than Ug.shs 199024.4 (2005 price level). Similarly, a household is generally poor if its real general expenditure per adult equivalent is less than Ug.shs 261717.1.

[22] Using the internationally comparable poverty line of $1 a day and the purchasing power parity exchange rate of about Ug.shs 478 to the US$1 in 2003 (World Bank, 2004) that reflect the living costs in Uganda, Yamano et al (2004) found 40 percent of rural Ugandan households to be poor. This is based on the $1 a day poverty line that is equivalent to $91.8 per person per year (using the official nominal exchange rate of about US$1 = Ug.shs 1900). Conversely, the authors found 52 percent of rural households to be living in poverty based on the national poverty line that is similar to what this study employs.

This implies that for every 100 rural households in Uganda, on average 32% had their expenditure on food requirement below the food poverty line, while 48% had their general expenditure below the national poverty line for the period 2001-2005. This indicates a slight decrease in the incidence of poverty[23] in rural Uganda.

The poverty gap ratio (P1) indicates the depth of poverty or how far the poor are from the poverty line, with the non-poor being given a distance of zero. The food poverty gap ratio reduced from 11% in 2001 to 9% in 2005, while the general poverty gap ratio also reduced from 18% to 16% in the same period. This implies that on average, household expenditure on food must increase by 11%, while that on a combination of food and non-food requirement must increase by 18%, if the poor are to come out of food and general poverty.

Sen's measure of poverty (Ps) denotes the severity of poverty that also includes the inequality among the poor. It is a weighted average of the headcount, the poverty gap and the gini coefficient for the poor (Deaton 1997). The method utilizes the square of the distance separating the poor from the poverty line into account. It also gives more weight to the poor, in order to account for the prevailing inequality among them. On average, the severity of food poverty is found to be 14% compared to 24% of general poverty in the period 2001-2005. The presence of inequality among the poor exacerbates the depth of poverty. Therefore, food expenditure must increase by 14% for the poor to get out of food poverty. General expenditure must increase by 24% for the poor households to get above of national poverty line.

Furthermore, Table 2 points out that 62 (20%) of the households were never poor, 50 (16%) households were in chronic poverty, whilst 197 (64%) households were in transitory poverty. Out of these, 101 (33%) households fell into poverty at least once, whereas 96 (31%) fell into poverty twice in the three periods. This implies that a very large share of rural households is in transitory poverty.

[23] The headcount ratio (P0) is the fraction of the population below the poverty line that reflects the incidence of poverty. The poverty gap ratio (P1) is defined as the per capita measure of the total shortfall of individual household welfare levels below the poverty line. In other words, the poverty deficit of the entire population or the sum of all the shortfalls divided by the population and expressed as a ratio of the poverty line (Deaton, 1997). Unlike the income gap ratio that it is defined only for the population that is poor, the poverty gap is defined over the whole population. Lastly, the Sen's measure (squared poverty gap) indicates the severity of poverty. It is able to give more weight to the very poor, in order to account for inequality among them.

V. THEORETICAL FRAMEWORK

We assume that households maximize their utility subject to a set of constraints where access to land from different sources is part of this constraint set. Land is one of the most important assets of rural households in Uganda and a primary basis for their livelihoods. Households will attempt to get access to additional land when the benefits of doing so are expected to be higher than the costs. It is mainly through the market that households can adjust their farm size in the short run while access to land through inheritance to a small extent can be influenced and size of inherited land of individual households change less frequently. However, household size and composition change over time such that the amount of inherited land per adult equivalent also changes over time. Cash and liquidity constraints may prevent households from accessing additional land through the market and their labor endowment limits their ability to utilize the land. We assume that households that are able to access land through the market have additional non-land resources and are therefore more able to improve their welfare through such land access. Based on this we test the following hypotheses:

H1) There is a positive correlation between household welfare and access to land through inheritance and through the market.

H2) After controlling for observable and unobservable factors that may explain land access, additional access to land enhances household welfare.

H3) Access to additional land through the market enhances household welfare more than access to additional land through inheritance.

VI. ECONOMETRIC MODEL ESTIMATION

Land access that includes a) land owned, b) land operated, and c) land acquired through the market, all are expected to be endogenous. This was confirmed by the findings of the post-estimation tests for endogeneity that are based on the Durbin (score) and the Wu-Hausman tests. These tests rely on the augmented regressors in the IV estimation, and their results are displayed at the end of Table A.1 in the Appendix. The two tests found the coefficient on the fitted residual term for each land access variable (from the first-stage OLS regression) to be statistically significant at 1-10 percent level. This provided strong evidence to reject the null hypothesis that each of the land access variables is exogenous. Linear functional forms for the estimated poverty impact model were adopted following the test results of various diagnostic fits in the form of scatter plots and nonparametric ‘lowess’ and ‘local linear’ regressions. The

plots are explained in detail at the end of Appendix A and found the relationship between household expenditure and each of the land access variables to be largely linear.

Residual Component (RC) Method

This study adopted the residual component (RC) method that is based on Holden et al. (2009; 2011) to give the main robust results. The RC approach is easy to compute and can generate robust estimates of the poverty impact equation of the endogenous land access variables under the assumption of strict exogeneity of the residual. It utilizes the residual component asset variable (=Productive Asset - Predicted Asset) to test the impact of the variation in asset endowment on household consumption expenditure, after the fixed household specific confounders have been cleaned out using a fixed-effects type of data transformation. The RC method is therefore able to control for biases due to the spurious correlations with omitted time-invariant variables. It is particularly useful when there are no strong and valid instruments to predict the endogenous variable of interest, and also when the data set constitutes short panels that can further limit the effects of omitted time-varying heterogeneity. In order to give parameters that are consistent, the RC approach does not rely on the strength and validity of the instruments, which is the Achilles heel of the IV approach. It instead requires relevant regressors that are strictly exogenous and limited presence of the time-varying unobserved heterogeneity that is correlated with the residual component and the outcome variable.

In this RC approach, each of the endogenous land access variables is first regressed on exogenous variables using household fixed-effects (FE) to clean out the unobservable and observable time-invariant household, farm and village characteristics that may cause endogeneity bias. Land access per adult equivalent, L_{ht}^{a} for a household h by year t is estimated in the first-stage equation (1) below, using household panel fixed-effects. The fixed-effects model is formulated as follows:

$$L_{ht}^{a} = \alpha_0 + \beta X_{ht} + \alpha_1 D_t + c_h + u_{ht} \qquad (1)$$

where L_{ht}^{a} denotes land access in form of land owned per adult equivalent, land operated per adult equivalent, and/or land acquired through the market per adult equivalent, X_{ht} is a set of exogenous variables that are time-variant such as; inherited land per adult equivalent, gini coefficient of land owned per adult equivalent by district, age of the household head, and age

of the household head squared. D_t represents year effects in form of dummy variables for time periods, c_h represents the time-invariant unobservable household, farm and village characteristics that can be captured with household fixed effects, and u_{ht} is the error term.

The FE method ensures model errors to be independent of individual households, $u_{ht} \perp c_h$. The individual household specific effects (the confounding incidental parameters) may, however, be correlated with regressors and may contain important endogenous unobservable factors that can influence land access and outcomes of such access. They are eliminated in equation (1) through the FE-estimator. The residual land access variable, $u_{ht} = \left(L_{ht}^a - \hat{L}_{ht}^a \right) \perp c_h$, is therefore not contaminated by unobservable time-invariant endogeneity that could bias estimates of returns to land if the actual land access variable, L_{ht}^a, was used directly for that purpose.

The error terms from equations (1) may then be seen as residual land access component variables cleaned for bias due to unobserved heterogeneity that is linked to time-invariant household characteristics. The impact of land access on household welfare is then estimated by including these residual land access component variables in the second-stage of the welfare impact equation (2) below, where also household fixed-effects are used to control for welfare measure biases due to unobserved household heterogeneity. The approach could therefore in this case also be called a double fixed-effects approach.

Each of the residual land access component variables in the second-step equation therefore, serves as the main poverty impact assessment test of interest. Also included in the second-step poverty impact estimation of the RC are the predicted land access variables that serve as additional controls for unobserved heterogeneity to enhance the robustness of the estimated parameters on the residual land access component variables.

We estimate the poverty reducing impacts of land access in the second-stage, using household fixed-effects model as specified in equation (2). The fixed-effects estimator eliminates welfare effects due to the time-invariant unobserved heterogeneity, ς_h. Household welfare in the outcome equation (2) is specified as a function of the generated residual land access

component variable from the first-stage equation, and other strictly exogenous variables including dummy variables for time periods.

$$y_{ht} = \beta_0 + \beta_1 Z_{ht} + \beta_2 \hat{L}^a_{ht} + \beta_3 \left(L^a_{ht} - \hat{L}^a_{ht} \right) + \beta_4 D_t + \varsigma_h + e_{ht} \quad (2)$$

where y_{ht} is expenditure per adult equivalent, Z_{ht} denotes the inherited land per adult equivalent, $\hat{L}^a_{ht}$ is the predicted land access per adult equivalent in form of owned, operated, or land acquired through the market, $\left(L^a_{ht} - \hat{L}^a_{ht} \right)$ is the residual land access component variables for owned, operated, or market acquired land that are used to test the poverty impact of land access, D_t represents year effects through dummy variables for time periods, ς_h is the welfare effect due to unobserved and observed time-invariant household heterogeneity captured by household fixed effects, and e_{ht} is the error term.

To the extent that time-varying endogeneity can affect both land access, and household welfare simultaneously, this may cause bias in the RC estimates. We proceed by assuming that time-varying endogeneity does not bias our estimates. We use instrumental variable methods to test the robustness of our results.

Robustness Checks

Censoring of the dependent variable in the first stage (in the case of market acquired land) may cause biased estimates in the linear fixed-effects (FE) model. However, it is important to note that recent evidence shows that nonlinear models may not give significantlydifferent results from models that are linear such as the OLS and panel FE model, when it comes to fitting marginal effects (Angrist & Pischke 2009). According to Angrist and Pischke (2009, p.94, 107 and 197-198;, 2010, p.11-12), the limited dependent characteristic of the regressor may not bias estimates of a linear model, since the legitimacy of any regression is derived from the conditional expectation function (CEF). The CEF is defined as the expectation of the dependent variable with a given vector of covariates held fixed.

Still, we conducted two types of sensitivity analysis of the major findings of the RC method. The first sensitivity analysis is based on the RC method for the reduced equation of land acquired through the market. This robustness check involved fitting the dynamic panel random-effects (RE) Tobit model (Wooldridge 2005) as an alternative to the linear panel

fixed-effects model. This alternative method has the advantage of controlling for the limited dependent variable (LDV) characteristic of the land acquired through the market. Unlike household fixed-effects, the Tobit model is able to produce conditional expectation functions (CEFs) that respect LDV boundaries of the key variable of interest, and fitted values that are positive (Angrist & Pischke 2009).

Specifically, the dynamic panel random-effects (RE) Tobit model was used to estimate equation (3) below instead of equation (1). It was used to predict land access through the market, and also to generate the corresponding residual land access component variable $\left(L_{ht}^{m}-\hat{L}_{ht}^{m}\right)$ that is utilized in the second-stage equation (2) as explained above. The dynamic panel random-effects Tobit model is specified as:

$$L_{ht}^{m}=\max(0,\beta X_{ht}+\alpha_1 D_t+c_h+u_{ht}^{*}) \tag{3}$$

where L_{ht}^{m} denotes land access through the market (rental, purchases and borrowing). The unobserved heterogeneity c_h is controlled for with a combination of random-effects and the lagged dependent variables in the initial period. These include market acquired land per adult equivalent in the initial period of 2001, $\left(L_{h0}^{m}\right)$ and a dummy variable for whether land was acquired through the market in 2001 $\left(D_{h0}^{lm}\right)$. The Dynamic RE Tobit model (equation 3) assumes strict exogeneity in the conditional mean sense, such that $E\left(u_{ht}^{*}\middle| X_{ht},D_t,c_h\right)=0.$ The unobserved heterogeneity is here modeled on the initial condition for the dependent variable as follows:

$$c_h=\psi+\eta L_{h0}^{m}+\lambda D_{h0}^{lm}+a_h,\qquad a_h\middle| L_{h0}^{m},D_{h0}^{lm},\approx Normal\left(0,\sigma_a^2\right) \tag{4}$$

where D_{h0}^{lm} is a dummy for access to land through the market in the initial period and L_{h0}^{m} is the degree of participation in the land rental market in the initial period. Model (3) can therefore be reformulated as:

$$L_{ht}^{m}=\max(0,\beta X_{ht}+\alpha_1 D_t+\psi+\eta L_{h0}^{m}+\lambda D_{h0}^{lm}+a_h+u_{ht}^{T}) \tag{5}$$

where u_{ht}^{T} given the regressors, $\left(u_{ht}^{T} \middle| X_{ht}, L_{h0}^{m}, D_{h0}^{lm}, D_{t}, a_{h}\right)$ has a normal$\left(0, \sigma_{u}^{2}\right)$ distribution, a_h denotes unobserved household-specific effect that may persist in the model due to time-variant and invariant factors, but is assumed to be independent from the regressors. The approach relies on a much stronger assumption of exogeneity in terms of idiosyncratic errors u_{ht}^{T} that are normally distributed. It implies that the explanatory variables in each time period are uncorrelated with the idiosyncratic error in each time period. Extreme regression outliers were removed to reduce the risk of biased results. Bootstrapping was used to obtain corrected standard errors, using 400 replications by re-sampling households.

Further sensitivity analysis was implemented using the standard instrumental variable (IV) two-stage least squares (2SLS) method. This involved using a linear combination of five instruments. Details of this IV estimation, the validity arguments for each instrument, tests for the instrumentation strategy, and the estimated IV results are presented in the Appendix. The instruments for each endogenous land access variable include:(i) the proportion of households in the smallest village (LC1) that can afford at least 2 meals a day, (ii) land in acres that both head and spouse brought in at the start of the household, (iii) the value (Ug.shs) of other in-kind (non-land and non-cash) assets that the head and spouse brought in at the start of the household, (iv) a dummy variable for the high agricultural potential (high rainfall) of the village, (v) age of the spouse of household head, and age of the spouse squared. The basic objection to this approach is that the instruments could potentially be correlated with the outcome (household welfare) variable in the second stage.

Undoubtedly, these instruments satisfied major tests of instrumentation as revealed by results shown in the lower section of Table A.1 in the Appendix. The F-test statistic for the strength of the instruments and the minimum eigenvalue in the four models are all higher than 10 and statistically significant at 1 percent level. This indicates that the five instruments are relevant and strong enough to predict each of the endogenous land owned, land operated, and market accessed land. The validity of the instruments could also not be rejected by testing for the over-identifying restrictions, based on Sargan and Basmann tests. The instruments are therefore correlated with the endogenous land access variables, but uncorrelated with the independent variables and the error term in the outcome equation.

VII. RESULTS AND DISCUSSION

Results for the first-stage estimation of the determinants of different modes of land access using the RC method are presented in Table 3. Land that is acquired through different modes of land access is shown as dependent variables. Land owned that also includes a mixture of land that is inherited and purchased is specified in model 1, operated land in model 2, and market acquired land including purchases in models 3 and 4. Land access variables in models 1, 2, and 3 were estimated with the household FE method. The market acquired land in model 4 was estimated with the dynamic panel RE Tobit method as part of the sensitivity analysis. Land access through the market is censored at zero for many observations. Here we assess, whether this censoring can affect the robustness of the estimated poverty impacts.

The predicted land access variable and the residual land access component variables (error terms) were generated from each of the four estimated first-stage equations, and included in the second-stage estimation of the welfare impacts that also denote the marginal effects of land. The four different first-stage models in Table 3 show strong joint effects of the specified strictly exogenous regressors on land access variables. The F statistics in models 1-3 and the Wald chi2 statistic in model 4 are statistically significant at 1 percent level.

TABLE 3
DETERMINANTS OF PER ADULT-EQUIVALENT LAND ACCESS ACROSS RURAL HOUSEHOLDS, A RC MODEL FIRST-STAGE ESTIMATION

	Panel Models with Household Fixed- Effects (FE)			Panel Tobit RE Model
	Per adult equivalent			
Independent variables	Owned land (1)	Operated land (2)	Market acquired Land (3)	Market acquired Land (4)
Inherited land per adult-equivalent (acres)	0.951***	0.962***	-0.140**	-0.309***
	(0.09)	(0.09)	(0.05)	(0.11)
Gini coefficient of land owned per adult-equivalent by district	1.179*	1.322**	0.868	0.777
	(0.61)	(0.64)	(0.58)	(0.54)
Age of household head (yrs)	0.015	0.012	0.009	0.008*
	(0.01)	(0.01)	(0.01)	(0.00)
Age of household head squared (yrs)	0.000*	0.000	0.000	0.000
	(0.00)	(0.00)	(0.00)	(0.00)
Market acquired land per adult-equivalent in 2001 (acres)				1.002***
				(0.03)
Dummy variable for access to land through the market in 2001				8.582***
				(1.91)
Dummy variable of year 2001	-0.130	-0.135	0.138	-8.956***
	(0.16)	(0.16)	(0.13)	(1.89)
Dummy variable of year 2003	-0.229***	-0.222**	-0.065	-0.127*
	(0.08)	(0.09)	(0.06)	(0.07)
Constant	-0.565	-0.390	-0.275	-0.246
	(0.63)	(0.62)	(0.54)	(0.30)
Panel level standard deviation (sigma_u)				0.686***
				(0.12)
Standard deviation of error term (sigma_e)				0.908***
				(0.13)
Number of observations	927	927	927	927
Number of households	309	309	309	309
F statistic	24.128	22.460	4.051	
Prob > F	0.000	0.000	0.001	
Wald chi2				1288.904
Prob > chi2				0.000
R2-within	0.246	0.245	0.031	
R2-between	0.170	0.156	0.036	
R2-overall	0.211	0.205	0.033	
Panel level standard deviation (sigma_u)	0.870	0.856	0.733	
Standard deviation of error term (sigma_e)	1.183	1.188	0.987	
Rho(fraction of variance due to u_i)	0.351	0.342	0.356	0.363
Uncensored observations				679
Left-censored observations				248
Right-censored observations				0.000
Log likelihood	-1278.756	-1282.805	-1110.348	-1131.082

Note: (i) Robust standard errors for models 1- 3, and Bootstrap (400 replications) standard errors for model (4) are in parentheses; (ii) * Significant at 10%; ** significant at 5%; *** significant at 1%.

The welfare effect of access to land is presented in Table 4. The residual land access component variable in each of the models 1-4 has a positive coefficient that is significant. Results in model 1 shows that holding the effect of other variables constant, a 1 acre increase in land owned per adult-equivalent increases household welfare (expenditure per adult-equivalent) by Ug.shs 129,230, which is significant at 10 percent. Model 2 indicates that households that access 1 additional acre of land operated per adult-equivalent enjoy Ug.shs 140,200 increase in their expenditure per adult-equivalent, also significant at 10 percent level.

TABLE 4
IMPACT OF LAND ACCESS ON HOUSEHOLD EXPENDITURE PER ADULT-EQUIVALENT (THE RC APPROACH)

	Per adult-equivalent (AE) land access (acres) and household expenditure/10,000 (Ug.shs)			
			Land acquired through the market (includes purchases)	
	Land owned	Land operated	Based on FE Land Access	Based on RE Tobit Land Access
Independent variables	(1)	(2)	(3)	(4)
Per adult-equivalent land inherited	2.685	0.652	3.646	5.659***
	(8.72)	(10.53)	(2.30)	(2.02)
Predicted per adult-equivalent land access	0.661	2.758	2.392	20.402**
	(8.10)	(9.89)	(13.13)	(9.39)
Residual land access component	12.923*	14.020*	20.772**	21.008**
	(6.66)	(7.44)	(9.54)	(10.51)
Dummy variable of year 2001	-4.340	-3.807	-4.630	-6.702
	(3.59)	(3.74)	(2.83)	(4.26)
Dummy variable of year 2003	-0.111	0.505	-0.032	2.063
	(5.25)	(5.48)	(4.18)	(4.21)
Constant	36.947***	34.923***	35.885***	23.553***
	(7.22)	(9.24)	(8.90)	(6.30)
Household fixed effects	Yes	Yes	Yes	Yes
Number of observations	927	927	927	927
Number of households	309	309	309	309
Chi2 statistic	13.165	12.463	18.380	29.562
Prob > chi2	0.022	0.029	0.003	0.000
R2-within	0.123	0.145	0.217	0.216
R2-between	0.215	0.198	0.266	0.278
R2-overall	0.157	0.165	0.236	0.240
Panel-level standard deviation (sigma_u)	25.406	25.609	24.490	24.281
Standard deviation of error term (sigma_e)	41.674	41.144	39.380	39.421
Rho (Panel fraction of variance)	0.271	0.279	0.279	0.275

Note: Bootstrap (400 replications) standard errors are in parentheses. * Significant at 10%; ** significant at 5%; *** significant at 1%

The coefficients of land are all significant and positive at 10 and 5 percent levels. The coefficients on land accessed through the market are significant at 5 percent levels in models 3 and 4 and are higher (20.8 and 21.0) in value than that of inherited (3.7 and 5.7). The coefficients on land accessed through the market are also higher than 12.9 for owned land in model 1 and 14.0 for operated land in models 2, although the difference was not significant. With one unit of the dependent variable being equal to Ug.shs 10,000, this implies that a one acre increase in land acquired through the market per adult-equivalent increases household expenditure per adult-equivalent by Ug.shs 207,720 - 210,080, which adds up to 79.4 - 80.3 percent of the poverty line income level (Ug.shs 261,717.1). This is strong evidence that land plays a significant role in influencing household welfare in rural Uganda. Land acquired through the market as well as through other means has strong positive welfare effects.

Noteworthy is the size of the coefficient (12.9) on the residual land access component variable in model 1 that is much higher compared to the corresponding coefficients on inherited land in models 3 and 4. This is attributed to land owned in model 1 that combined land sales, purchases, and inheritance. The finding makes sense therefore, that the coefficient in model 1 lies somewhere in between the two coefficients on inherited land and market accessed land. The study finding that the magnitude of the estimated welfare effects were larger on market-accessed land than on inherited land is a further indication that access to additional land through the market, including borrowing, may be associated with stronger poverty reducing effects compared to additional land that is accessed through non-market modes.

We cannot therefore reject the three hypotheses formulated in the theoretical framework. Welfare of households increases with access to land and this is more than a correlation between wealth and land access, the results are robust to alternative controls for endogeneity of land access. Furthermore, additional access to land through the market appears to have a stronger welfare improving effect than access to additional land through inheritance. This is a logical consequence of land markets transferring land to more efficient producers.

Further robustness checks

The 2SLS instrumental variable (IV) models for each of the land access variables are presented in detail in Appendix A. While results of the IV second-stage estimation are summarized in Tables A.1, those of the first-stage IV estimation are found in Table A.2. The

results in Tables A.1 are in line with the key findings of the residual component (RC) approach in Table 4. However, they show relatively lower marginal effects of each of the land access variables compared to the corresponding estimates of the RC model estimation.

The significantly larger IV coefficients on market acquired land in relation to coefficients on inherited land is a further confirmation of our earlier RC findings that land access through the market including borrowing, generates stronger poverty reduction effects compared to additional land access through inheritance. Results of the standard IV approach did not change significantly, even when we employed the G2SLS panel random-effects[24] and limited-information maximum likelihood (LIML) estimation to estimate the poverty impact equation of land access.

VIII. CONCLUSION

This paper has estimated the welfare impacts of land access through inheritance, a combination of inheritance and other methods of acquisition, and through the market and borrowing in rural Uganda. The uncovered evidence indicates that land scarcity is increasing, and this has made land access an important poverty and welfare indicator in Uganda where more than 90% of the poor live in rural areas. Our analysis shows that land, whether accessed through the market or non-market ways plays an important role in enhancing household welfare. Households with more of either owned land, operated land, or market-accessed land were shown to gain a significant welfare-improving effect of this better land access after we have controlled for endogeneity in land access and for unobserved heterogeneity effects on welfare. The other significant finding was that better land access through the market has a stronger welfare-improving effect than better land access through inheritance. This is likely to be the case because land markets to a larger extent transfer land to more efficient producers. Access to a balanced panel data set and application of appropriate panel data methods has made it possible to estimate these new results, which demonstrate that land markets enhance efficiency as well as contribute to poverty reduction.

[24] Results of the G2SLS panel random-effects estimation and that of limited-information maximum likelihood (LIML) estimation of the poverty impact equation of land access are available and can be obtained from the authors upon request.

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APPENDIX A

In this Appendix, we present a brief description of the standard IV (2SLS) model that use a linear combination of five instruments as indicated in the section five of the main paper. There can be a positive correlation between food security and access to land, especially among the rural households. Farm households can increase their agricultural food production and welfare overtime, if the land-poor (or near landless) but efficient households are able to access land from the land-rich households. The proportion of households in the smallest local government (LC1) that can afford at least 2 meals a day can therefore, be a reliable instrument for land access at the village level.

We also contend that households with more access to land in the current period may have also enjoyed relatively more land endowments at the start of their households. Current land endowments and the possibility of the increased land accumulation over time may largely be correlated with initial land and non-land assets that the head and the spouse brought in at the start of the household. Still, land scarcity is likely to be more pronounced in areas with a reliable rainfall pattern, due to high population pressure. The agricultural potential of an area can be an effective signal of the level and the underlying dynamics of land access across rural farm households in any given agricultural period. Undoubtedly, the age of the spouse tends to correspond highly with different stages of the life-cycle that are specific to different levels of food requirements and demand for different productive assets in the household. We expect age of the spouse to be a suitable instrument for land access over time.

Results of the 2SLS standard IV model estimation are presented in Table A.1. In the case of the corresponding first-stage IV estimation, results are summarized in Table A.3. The estimated IV first-stage equation for each of land access variables in the four model specifications indicate adjusted R-squared values that are between 12% and 27%. This implies a reasonable overall fit and considerable variation in land access that is explained by the exogenous and instrumental variables.

Different tests of the instrumentation are summarized in the lower section of Table A.1. The first test is based on the null hypothesis that instruments are weak. The F-statistics for the joint significance of instruments in each model (Table A.1) are found to range between 17.33 and 18.70, with a p-value of 0.0000. These F-values are higher than 10, and satisfies the widely used rule of thumb (greater than 10) for instruments that are considered not to be weak. This is

confirmed by the minimum eigenvalue statistic that is also greater than 10, suggesting that these instruments are not weak. However, these two statistics are seen to be considerably lower than the critical value (29.18) of the 2SLS estimator (when a distortion of a 5% is tolerated in the Wald test) that includes a 10% at most of the true size of estimates. In this case, we do not reject the null hypothesis that the joint effect of the instruments is weak.

The test of endogeneity of land access variables based on these instruments (Table A.1) show significant (1-10 % level) and relatively high values (3.15-8.07) of the Durbin (score) chi2 statistic, and (3.14-8.09) of the Wu-Hausman F statistic. These results imply a strong rejection that all the land access variables are exogenous. We therefore, conclude that land owned, land operated, and market accessed land are all endogenous.

The test of over-identification restrictions is based on the post estimation sargan chi2 statistic that ranges from 5.45-6.81, and the Basmann chi2 statistics of 5.43-6.79. These two statistics have p-values that are clearly insignificant, implying that the validity of the 5 overidentifying restrictions in each model specification could not be rejected. These five instruments were found to be strong and relevant to predict the endogenous land access variables according to different tests of instrumentation strategy presented above.

In the case of the main residual component model, several diagnostic regression tests in form of scatter plots, nonparametric 'lowess' and 'local linear' fits of household expenditure on each variable of land access were conducted to verify whether there are serious nonlinearities between household welfare and land endowment. Plots of these regression specification tests for the 'actual land access variables' and the corresponding 'residual land access component variables (error term)' are summarized in Figures A1.1-A1.7 in Appendix A1, P.218-221. It is evident from these plots that the relationship between household expenditure and each of the land access variables is largely linear. Linear functional forms were therefore adopted for the estimated poverty impact model in this article, although new advances in the contemporary empirical work play down the importance of functional form concerns. The evidence based on the conditional expectation (CEF) function shows that linear models can also be remarkably robust and can provide the best linear approximation even with nonlinear CEF (Angrist & Pischke 2010). Besides, estimates of the two-stage least square (2SLS) are interpreted as the average casual effect and it makes no distinction whether the key endogenous variable is continuous or non-linear (or heterogeneous).

TABLE A.1
IMPACT OF LAND ACCESS ON HOUSEHOLD EXPENDITURE PER ADULT-EQUIVALENT, (2SLS) IV APPROACH

	Per adult-equivalent (AE) land access (acres), and expenditure/10,000 (Ug.shs)			
	Land Owned	Land Operated	Land Access through Market	Land Rented-in & Purchased
Independent variables	(1)	(2)	(3)	(4)
Land access per adult-equivalent (acres)	8.188**	7.825**	10.445***	10.362***
	(3.37)	(3.43)	(3.87)	(3.87)
Land inherited per adult-equivalent (acres)	-3.213	-2.891	6.387***	6.489***
	(3.55)	(3.59)	(2.10)	(2.12)
Dummy variable for year 2001	-2.396	-2.604	-5.127	-5.312
	(3.58)	(3.57)	(3.37)	(3.39)
Dummy variable for year 2003	2.130	1.943	0.833	0.530
	(3.61)	(3.60)	(3.39)	(3.39)
Constant	29.825***	29.631***	29.740***	30.392***
	(3.99)	(4.21)	(3.74)	(3.58)
Number of observations	927	927	927	927
F statistic	3.006	2.832	3.440	3.406
Prob > F	0.018	0.024	0.008	0.009
R-squared	0.133	0.134	0.182	0.178
Adjusted R-squared	0.129	0.130	0.179	0.174
Root mean squared	43.041	43.011	41.787	41.904
Test for weak instruments based on the 2SLS; Ho: Instruments are weak				
First-stage adjusted R-sq	0.2724	0.2736	0.1213	0.1260
F-statistic for joint significance of instruments	17.6416	17.328	18.1532	18.6996
Prob > F	0.0000	0.0000	0.0000	0.0000
Minimum eigenvalue statistic	17.6416	17.328	18.1532	18.6996
2SLS Size of nominal 5% Wald test (at 10%)	29.18	29.18	29.18	29.18
Tests of endogeneity:Ho: variables are exogenous				
Durbin (score) chi2(1)	3.14825	4.1931	7.96559	8.07358
p-value	0.0760	0.0406	0.0048	0.0045
Wu-Hausman F(1,921)	3.13853	4.18489	7.98262	8.0918
p-value	0.0768	0.0411	0.0048	0.0045
Tests of overidentifying restrictions:				
Sargan (score) chi2(5)	6.09031	6.8139	5.45208	5.48036
p-value	0.2975	0.2349	0.3632	0.3601
Basmann chi2(5)	6.06446	6.79031	5.42517	5.45348
p-value	0.3000)	0.2367	0.3662	0.3631

Note: (i) Unadjusted (nonrobust) standard errors are in parentheses;
(ii) * Significant at 10%; ** significant at 5%; *** significant at 1%;
(iii) An option "small" was used to enhance the efficiency of the IV estimates. It allows for the total sample (N) adjustment "$(N/N-K)$" to the degrees of freedom in the variance-covariance matrix of parameters (K), and also reports small sample F and t statistics instead of Wald chi2 and z statistics.

TABLE A.2
RESULTS OF THE FIRST-STAGE (2SLS) REGRESSION OF LAND ACCESS

Independent variables	Land Owned (1)	Land Operated (2)	Land Access through Market (3)	Land Rented & Purchased (4)
Land inherited per adult-equivalent (acres)	0.900***	0.894***	-0.211***	-0.221***
	(0.06)	(0.06)	(0.05)	(0.05)
Dummy variable for year 2001	-0.425***	-0.448***	-0.030	0.025
	(0.12)	(0.12)	(0.10)	(0.10)
Dummy variable for year 2003	-0.291***	-0.285***	-0.102	-0.073
	(0.10)	(0.10)	(0.08)	(0.08)
Instrumental variables				
Proportion of households in the LC1 that can afford at least 2 meals a day	-0.438***	-0.466***	-0.246*	-0.164
	(0.16)	(0.16)	(0.13)	(0.13)
Land (acres) brought in by head and spouse at the start of the household	0.027***	0.026***	0.014***	0.015***
	(0.00)	(0.00)	(0.00)	(0.00)
Value (shs) of other in-kind assets brought in by head and spouse at the start of household/1000	0.000***	0.000***	0.000***	0.000***
	(0.00)	(0.00)	(0.00)	(0.00)
Dummy for agricultural potential/high rainfall in a community (1= bi and uni high, 0= otherwise)	-0.110	-0.182**	-0.077	-0.054
	(0.09)	(0.08)	(0.07)	(0.07)
Age of spouse of household head (yrs)	0.021	0.014	0.020	0.024*
	(0.02)	(0.01)	(0.01)	(0.01)
Age of the household head's spouse squared (yrs)	-0.000	-0.000	-0.000	-0.000
	(0.00)	(0.00)	(0.00)	(0.00)
Constant	0.681**	0.976***	0.370	0.167
	(0.34)	(0.34)	(0.29)	(0.28)
Number of observations	927	927	927	927
Wald chi2	39.528	39.761	15.203	15.833
Prob > F	0.000	0.000	0.000	0.000
R-squared	0.280	0.281	0.130	0.134
Adj R-squared	0.272	0.274	0.121	0.126
Root MSE	1.243	1.231	1.034	1.023

Note: (i) standard errors are in parentheses; (ii) * Significant at 10%; ** significant at 5%; *** significant at 1%.

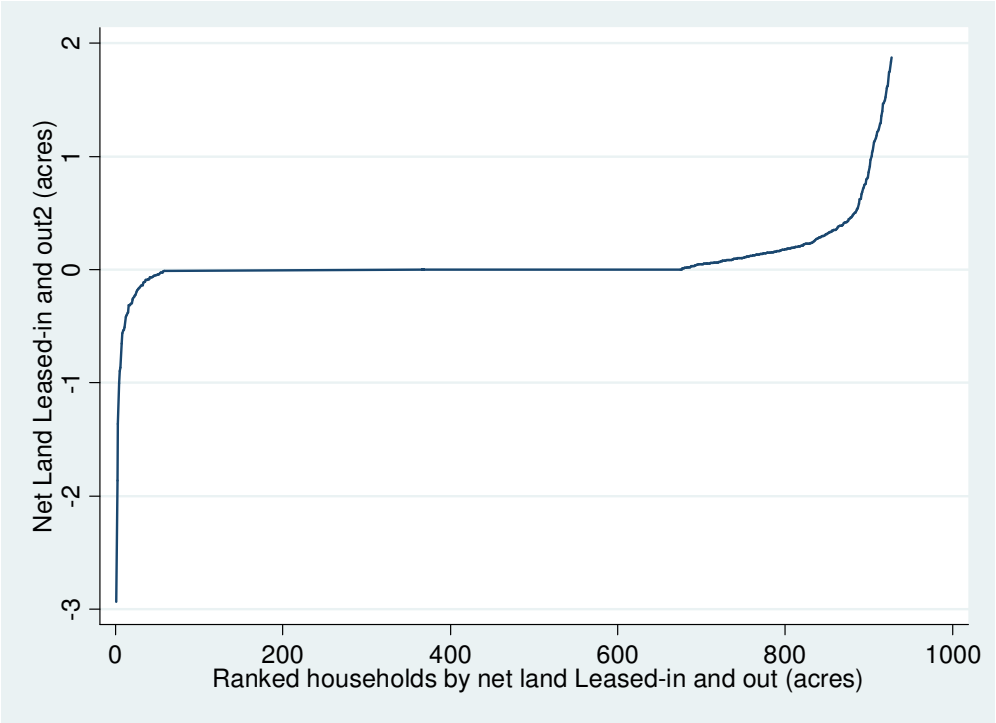

FIGURE A.1. NET LAND RENTED IN, 2001-2005

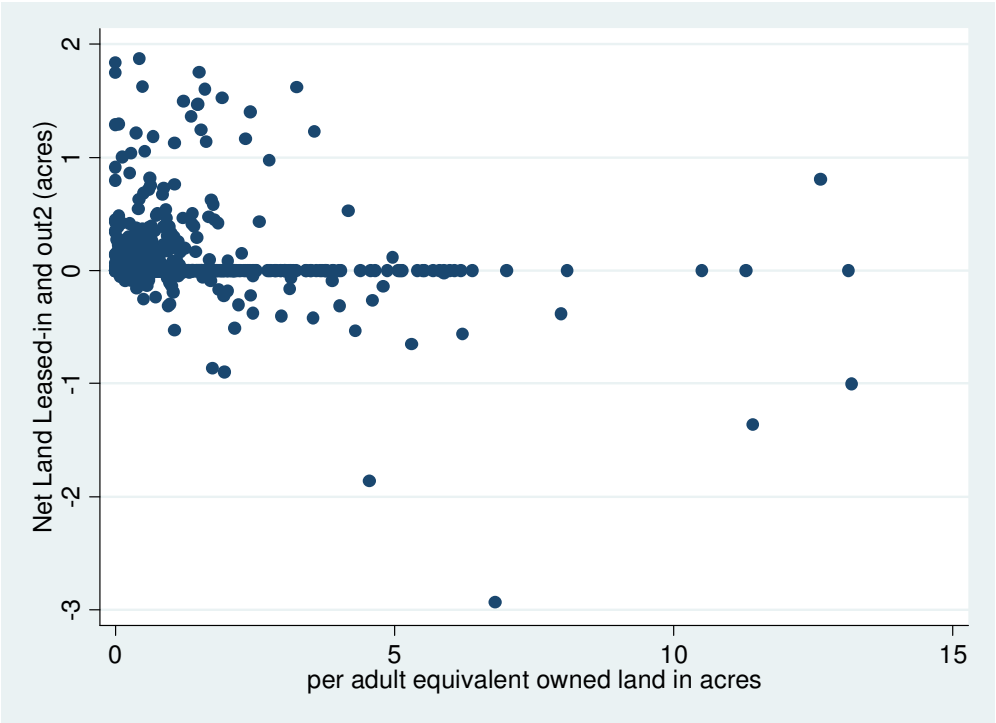

FIGURE A.2. NET LAND RENTED IN VERSUS LAND OWNED (ACRES), 2001-2005

Paper II

Changes in Human Capital and Impact on Household Welfare in Uganda

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ABSTRACT: *This article employs the income approach to compute the value of household human capital. A Mincerian earning function at individual level is estimated to calibrate returns to human capital investments in form of years of formal schooling and access to on-job training for working adult household members. The impacts of changes in human capital endowment and health shocks to human capital on household expenditure per adult equivalent are estimated. Using a micro panel data of 304 rural Ugandan households surveyed in 2001, 2003, and 2005, a control function approach combined with the Mundlak-Chamberlain device to unobserved effects was employed to generate unbiased estimates. The analysis reveals that human capital across households increased steadily over the five year period. Poverty reduction effects of increased investment in human capital are found to be positive and highly significant. The incidence of idiosyncratic health shocks to human capital in terms of deaths has an insignificant negative effect on household welfare. The unexpected sicknesses within households appear not to have significant effects on the consumption expenditure per adult-equivalent.* (JEL J24, O12, and O15)

Key words: Endogeneity, human capital gain, health shocks, unobserved heterogeneity, poverty impacts.

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Changes in Human Capital and Impact on Household Welfare in Uganda

1. Introduction

Investment in education is widely believed to reduce poverty by creating and transforming wealth (Fan & Chan-Kang 2004; Fan et al. 2007). People invest in themselves[1] to enhance their welfare and to access a range of livelihood choices (Schultz 1961; Le et al. 2003). This perception notwithstanding, the existing evidence on the impact of education on the productivity and welfare of agricultural households in developing countries is mixed. Whereas most studies (Schultz 1961; Black & Lynch 1996; Jolliffe 2002; Kurosaki & Fafchamps 2002; Kurosaki & Khan 2006) demonstrate that education has a positive and significant effect on productivity, there are others (Benhabib & Spiegel 1994; Fafchamps & Quisumbing 1999; Temple 1999; Appleton 2001; Pritchett 2001) that illustrate insignificant productivity effects of access to education especially in the agricultural sector.

Access to additional education is reputed to increase earnings that by and large, tend to be much higher in poor countries compared to rich countries (Bhalotra & Heady 2003). For example, the average rate of returns[2] to investment in another year of schooling are estimated to be second highest in Sub-Saharan Africa (SSA) at 11.7%, after a 12.0% in Latin America and Caribbean regions (Psacharopoulos & Patrinos 2002). Yet, despite these high returns, a substantial number of households in SSA remain in poverty, even when they have invested in education (Appleton 2001). The notion that economic growth may not be linked to educational attainment (Benhabib & Spiegel 1994; Temple 1999; Pritchett 2001), has created controversy and the need to clearly understand the usefulness of education in improving the welfare of the poor. This paper therefore, makes a systematic analysis of household investment decisions in human capital and provides additional insights on the welfare effects of access to additional human capital across rural farm households.

[1] We measure human capital as the annual present value of expected aggregate future earnings or purchasing power for all adult-working members in the household, i.e. current earnings plus the expected present value of future earnings (Hall 1978). Human capital may include a cluster of such factors as education level, literacy, knowledge, skills, competencies, attributes, nutrition, health and experience that can improve the technical and allocative efficiency of labor input in terms of quality and future productivity advantage (Black and Lynch 1996; Ray 1998; Bardhan and Udry 1999; Jolliffe 2002; Kurosaki and Khan 2006).

[2] Psacharopoulos and Patrinos (2002) indicate that average returns to an additional year of schooling were highest in the Latin America and Caribbean regions at 12.0% compared to 11.7% in Sub-Saharan Africa region, 9.9% in Asia, 7.5% in OECD, and 7.1% in Europe/Middle East/North Africa.

Evidence on asset-based risk coping strategies under borrowing constraints and other factor market imperfections show that income of rural agricultural households can be susceptible to great uncertainty due to shocks (Deaton 1990; Deaton 1991; Deaton 1992a). Expected and unexpected disasters such as sickness and deaths can create unmediated risk and vulnerability that affects the households' investment strategy. In order to manage these risks, households engage in forward looking intertemporal plans and adopt various informal risk management schemes. Households can for example, choose to acquire affordable insurance by building up savings for the future in form of low return and low risk buffer assets (Deaton 1991; Deaton 1992b). They can also invest in higher yielding productive assets such as human capital, livestock and land (Rosenzweig & Wolpin 1993; Zimmerman & Carter 2003).

In Uganda, some studies have examined the impact of education attainment on household productivity and welfare (Bigsten & Kayizzi-Mugerwa 1995; Appleton & Balihuta 1996; Appleton 2001; Deininger & Okidi 2003). Appleton & Balihuta (1996) show that agricultural households in rural Uganda derive significantly higher returns from the first seven years of primary schooling compared to returns from years of secondary level schooling that appeared to only benefit those in wage employment. Appleton (2001) found significant and increasing productivity effects of education on earnings in sectors of wage employment and non-agricultural self-employment, but concluded that returns to education in the agricultural sector were insignificant. Bigsten & Kayizzi-Mugerwa (1995) concur that the education has insignificant productivity effect on rural agricultural transformation, while Deininger & Okidi (2003) showed that the average years of schooling in a household is important for growth and poverty reduction. All these studies employed econometric methods that assumed education to be exogenous to household decisions, and therefore did not adequately control for the endogeneity of access to education, which raises questions on the validity and consistency of reported empirical results. The inability to effectively control for the problems of omitted-variable causation and reverse causality may lead to biased results. While self-selection into higher education can lead to upward bias in these studies, the opposite may also be true.

The major aim of this study is to assess the poverty reducing effects of changes in human capital in the wake of idiosyncratic human capital shocks. Specifically, this study assesses: (i) the extent to which changes in measured human capital affects real household consumption expenditure per adult equivalent and, (ii) whether variation in the health shocks to human capital in terms of death incidences and sick-days have a significant impact on household

welfare. Here the question is whether rural households are able to protect themselves against such shocks through consumption smoothing. We employ the control function (CF) method combined with the Mundlak-Chamberlain device to unobserved effects to compute welfare effects of human capital and human capital health shocks. The CF estimation is able to control for the effects of the time-invariant and time-varying household specific unobserved heterogeneity, and can produce more efficient and precise estimates compared to a 2SLS estimator.

The paper is organized as follows. Section 2 provides an overview of labor market characteristics, poverty levels and policies that promote education in Uganda. Section 3 presents the conceptual framework that formalizes the estimated empirical model. Section 4 describes data sources and measures of household welfare. The computation of human capital stock and the econometric estimation strategy is presented in section 5. Descriptive statistics are presented in section 6. Section 7 discusses the empirical findings, and Section 8 concludes.

2. Labor Market, Poverty and Education Policies in Uganda

The majority (85%) of Uganda's population resides in rural areas that are characterized by high growth rate in labor force. The total labor force[3] in Uganda increased by 3.6% per year between 2002/03 and 2005/06 (UBOS 2007; UBOS 2009). Seventy percent of the working population is self employed in agriculture and fisheries. A significant number of rural households are also reported to be active in diverse livelihood strategies (Canagarajah et al. 2001; Smith et al. 2001; Bagamba et al. 2007) including non-farm activities that seems to be on the increase.

Poverty reduction remains a major goal of economic development in Uganda, and access to education is considered to be crucial in attaining this important goal. Recent studies indicate that the percentage of people living below the poverty line dropped from 38.8% in 2003 to 31.1% in 2006 (UBOS 2009). However, poverty in rural areas averaged higher at 34.2% in 2006 compared to 13.7% in urban areas (UBOS 2006; UBOS 2008). And while this pose a challenge to achieving the Millennium Development Goal of halving poverty levels by 2015, and a major national goal of reducing the incidence of income poverty to less than 10% by 2017, there seems to be good progress on this front. The population estimated to be living below income poverty is estimated to be 24.5%, implying a reduction of poor persons from 8.4

[3] Total labour force in Uganda increased from 9.8 million persons in 2002/03 to 10.9 million persons in 2005/06 at a participation rate of 82% (UBOS, 2009).

million in 2005/6 to nearly 7.5 million in 2010. A new five-year National Development Plan was launched in 2010 to guide the country's development programs, and is expected to transform Uganda from a peasant to a modern and prosperous country within 30 years.

2.1 Education Policies in Uganda

The government of Uganda emphasizes the development of human capital through education and good health care for economic development. The Education Policy Review Commission (EPRC) that was appointed in 1987, the 1992 Government white paper (GWP) on education, and the subsequent work of the National Curriculum Development Centre (NCDC) adopted several reforms (Ministry of Education and Sports 2004; Roebuck & Buchan 2006). The reforms were meant to expand the functional capacity of educational structures, and to increase equitable access to basic education for all people in Uganda through the Universal Primary Education (UPE) programs (Ministry of Education and Sports 2004). The UPE program was initiated in 1997, and ensures that all children aged 6 years and above be enrolled to school. The government pays tuition fees and is also responsible for the construction of classrooms throughout the country and all daily costs needed to enhance the quality of education.

Various initiatives have been put in place to improve access to all levels of education and to reduce gender disparities in education attainment. A Post Primary Education Training Policy (PPET) in form of Universal Secondary Education (USE) and vocational training institutions was put in place in 2007 to cater for the increasing number of children graduating from primary schools. This is supported by other strategic plans and acts of parliament, including the Education Sector Strategic Plan (ESSP) 2004-2015 and the University and Other Tertiary Institutions Act 2001 (Ministry of Education and Sports 2004) that regulate higher education, implement the reforms, improve management, sustain quality education and provide legal framework to the expanding education sector.

Education has therefore, become the largest component of government spending with the largest budget share of the national budget. The budget shares for education, agriculture and health sectors were 22.92%, 2.1% and 6.46% respectively in the financial year of 2003/04 (Enyimu et al. 2006), these sectoral budget allocations changed to 15.3% for education, 4.4% for agriculture, and 10.4% for health sector in the financial year of 2009/10 (Ministry of Finance Planning and Economic Development 2010). Primary enrollment is reported to have increased from 2.8 million in 1997 to 7.6 million in 2004 (UNESCO 2000; Ministry of

Education and Sports 2005; Nishimura et al. 2008), to 8.7 million in 2009/10. The policy to liberalize education has increased enrollment, the number of universities, and literacy rate that is now estimated to be 73% in 2009/10 compared to 69% in 2005/06 among the population above 10 years.

3. Conceptual Framework

This section formulates an empirically tractable structural dynamic model of investment behavior in a productive asset based on the work of Rosenzweig & Wolpin (1993). The model assumes that household income is generated from returns to investment in human capital amidst risk, borrowing constraints and subsistence constraints in each period. We contend that differences in adult-worker skills[4] are created by diverse levels of education attainment, experience, and good health, and can lead to significant fractional variation in earnings and household output (Kremer 1993). Consider the stock of human capital[5] that is defined by the level of aggregate present value of future discounted purchasing power of all adult working members in a household that are above 16 years of age. A household problem is to maximize the present value of the expected lifetime utility over a finite horizon. Utility at any time, t, $u\left(C_t - C_{\min}\right)$ depends on the consumption of a single non-storable aggregate commodity, C_t above a minimum subsistence consumption level, $C_{\min}$.

A household h owns an amount of land (A) at time t that can be rented-out, added-to or even divested and can also accumulate human capital through access to additional education or on-job training. Assume a general utility function per period with respect to flexible consumption such that a household problem is to maximize:

$$E_t \sum_{t=\tau}^{T} \delta^{t-\tau} u\left(C_t - C_{t,\min}\right) \tag{1}$$

[4] Work skill may be seen as the product of investment in human capital, and can include both cognitive and non-cognitive skills such as self-regulation, motivation, adventurous, perception, reasoning, and judgment (Heckman, 2007). Kremer (1993) defines worker skill as the expected percentage of maximum value the product retains if a worker performs the task. In this paper, we adopt the standard efficiency units' formulation of labor skill that allows quantity of labor supply to be substituted with quality in each period.

[5] Most studies on human capital assume present value maximization of earning power as defined in the work of Mincer (Mincer 1974; Krueger and Lindahl 2001; Wößmann 2003) on the assumption that individual earnings are influenced by acquired skills and education level. While these studies analyze earning distribution across individuals using Mincerian earning functions, other studies are based on the work of Ghez and Becker (1975) that focus on explaining consumption expenditure and labor supply of individuals as defined by life-cycle budget constraints.

where E_t is the expectation operator that is based on the information set at time t, δ is the subjective discount factor. The greater the level of aversion to risk, the higher the likelihood of market failure, and the inability of farm households to maximize returns to assets, given the production function. The decisions of a household to produce and consume therefore become interrelated in the presence of information asymmetry and imperfect markets for some of the products and factor inputs. Assuming quasi-separability[6] of production and the fact that household income is endogenously determined (Jacoby & Skoufias 1998), one can model the production side of the agricultural household, and this implies that household consumption is a function of profit, costs, risks and preferences.

A household generates income through agricultural crop production that is considered to be a two-stage process denoted as planting (p) and harvesting (h). In each period, initial decisions are made on how to combine adult human capital, with land and other variable inputs such as seeds, fertilizers and labor. Initial costs are incurred prior to the realization of the production shock. The harvesting stage employs only variable inputs, primarily labor, to reap potential yield after the resolution of uncertainty. Production is accordingly:

$$Q_{ht} = q_t\left(H_t, A_t, X_t^p, X_t^h, \theta_{ht}^k\right) \tag{2}$$

where Q_{ht} represents agricultural output, θ_{ht}^k denotes the time-varying random shock to production that is household specific, and also in form of idiosyncratic health shocks such as deaths and sicknesses. The optimal farm income (profit) in period t is thus given by:

$$\pi_{ht}^g = p_t^q q_t\left(H_t, A_t, X_t^p, X_t^h \theta_{ht}^k\right) - \sum p_t^X X_t - wH_t - rA_t \tag{3}$$

where $H_t \in \left(0,10000,....,H^{\max}\right)$ is the value (in Uganda shillings (Ug.shs)) of human capital stock per adult equivalent, p_t^q is the price of the agricultural product, while p_t^X is the vector of prices for variable inputs used in the planting (X_t^p) and harvesting (X_t^h) periods. The return to human capital (quality labor) is defined by the wage rate, w while that on land that is exchanged on the market is determined by land rental price r. The derived household

[6] The production function is quasi-separable, if its input space can be decomposed or broken into various stages, where intermediate inputs are produced and then combined with other intermediate inputs to produce the final output (Gordon, 2011). Whilst, this gives a potentially useful measure of marginal product in a way that avoids more complex analysis by reducing the number of parameters to be estimated, the derived marginal distributions may not be combined to form the joint distribution for the whole model (Thomas and Bradley, 2001).

optimization problem is however intractable due to various choice variables and solving the problem repeatedly at alternative parameter values may not be feasible. The presence of pre-shock variable inputs cannot allow the separation of variable input decisions from the dynamic problem, and also the allocation of post-shock harvesting inputs to maximize single period profits. We therefore employ the restricted[7] (farm income) function conditional on human capital stocks held at the beginning of the period following the work of Rosenzweig and Wolpin (1993. Pg.230) to retrieve technology parameters as indicated in equation (4):

$$\pi_{ht}^{r} = \pi_{t}\left(H_{t}, A_{t}, \theta_{ht}^{k}\right) \tag{4}$$

The farm income function for a given land operated is therefore:

$$\pi_{ht} = \pi_{0} + \sum_{j=H_{\min}}^{H^{\max}} \pi_{1j} D_{tj} + \pi_{2}\theta_{ht}^{k} + \pi_{3} z_{ht} \tag{5}$$

where $D_{tj} = 1$ if the endowment value of household human capital per adult-equivalent at time, t, is, $j = 0,10000,....,H^{\max}$ (i.e. between the minimum and maximum sample level). Household characteristics (Z_{ht}) can also be incorporated to capture the effects of experience and gender. Assume also that the household has a form of disaster insurance[8] (Rosenzweig and Wolpin, 1993), implying that consumption is equal to the minimum consumption plus $v > 0$, where v is negligible. Consumption must therefore be equal to household farm income net the cost of producing additional units of human capital as long as the consumption minimum is satisfied. Net investment in human capital, w_t at time, t equals gross investment $(H_t - H_{t-1})$ net of depreciation $(\delta_t H_{t-1})$, and human capital that is lost through sickness and deaths of household members, l_t^H. Human capital stock therefore evolves according to:

$$H_{t} = H_{t-1} + \left(\left(H_{t} - H_{t-1}\right) - \delta_{t} H_{t} - l_{t}^{H}\right) = H_{t-1} + w_{t} \tag{6}$$

$$\text{where, } w_{t} = gH_{t-1} + InvH_{t-1} - \delta H_{t-1} - l_{t}^{H}. \tag{7}$$

where gain in human capital stock due to growth in experience is denoted by gH_{t-1} while human capital derived from investment in further schooling is represented by, $InvH_{t-1}$. The

[7] Assuming that all household consumption smoothing above subsistence level is only achieved based on the returns in every period.

[8] Households may have a fixed insurance premium paid each period, subtracted from π_t and probably contained in π_0 and in form of remittances or transfers from non-resident family members (Rosenzweig and Wolpin 1993).

human capital stock at time t equals the stock in the previous period plus net investments in human capital (w_t) such that:

$$\begin{aligned} C_t &= \pi_t - p^h(w_t) > C_{\min} + v \\ C_t &= C_{\min} + v;\ \text{if } \pi_t - p^h(w_t) \le C_{\min}, \end{aligned} \tag{8}$$

where p^h is the real cost per unit human capital stock accumulated such that:

$$C_{ht} = f\left(\pi_t((H_{t-1} + g.H_{t-1} + InvH_{t-1} - \delta H_{t-1} - l_t^H), A_t, p^h, \theta_{ht}^k)\right) > C_{\min} + v \tag{9}$$

The reduced equation (9) indicates that consumption is a function of resources at hand that can be set aside for future consumption. These are resources in form of income that is derived from household human capital net the cost of producing additional human capital among adult household members in each period, and net of the value of human capital lost through depreciation, sicknesses and deaths of household members as long as the minimum consumption is satisfied.

4. Data and Welfare Indicators

This study utilizes a three-period household panel data set collected in 2001, 2003, and 2005 by two research projects. The first survey was conducted in 2001 by International Food Policy Research Institute (IFPRI), and covered two thirds of Uganda including Southwest, Central, Eastern, and some areas in northern Uganda. A stratified sampling procedure was employed based on a classification of Uganda's territory according to the agricultural potential, market access and population density. A total of 450 households in 107 communities were interviewed in the first survey. The subsequent two surveys were conducted in 2003 and 2005 as part of the Research on Poverty, Environment, and Agricultural Technologies (REPEAT) project. In these surveys, 3 districts that were part of the earlier IFPRI study areas were dropped due to insecurity in the North and Northeastern parts of Uganda, and instead 94 out of the previous 107 communities were selected. Because of the change in the sampling frame in 2003, only 333 households out of the 450 households in the baseline survey of 2001 were included in the 2003 REPEAT survey, and more 20 households dropped out in the 2005 survey. This study is therefore based on a balanced panel data of 304 households, after dropping 9 more households with missing values of crop production and farm size in one or two periods. The analysis is conducted on 912 observations from 26 districts of Uganda.

4.1. Household Welfare

Household welfare is measured as the annual consumption expenditure and income[9] per adult-equivalent. The two measures of welfare were standardized to adult-equivalent, and adjusted to 2005 prices to enable comparability across households. Real expenditure that forms the basis of poverty impact estimation in this study was constructed from cash expenditure for consumption and value of consumption of home produced goods. The real average income of households is noted to be much lower than the corresponding real average expenditure, especially in the initial year of 2001. There may be practical challenges of measuring income of self-employed rural agricultural households, and these may to a large extent limit the disclosure of all the concealed income. Still, we contend that the welfare effects that are specific to household consumption expenditure are more robust and reliable.

5. Computation of Human Capital and Econometric Estimation

In this section we employ the Mincerian earning function to estimate human capital of households based on the individual-level panel data of working age household members. Human capital theory indicates that education and the stock of human capital can be expressed in money units based on a human capital earnings function (Mincer 1974; Psacharopoulos & Patrinos 2002; Le et al. 2003; Wößmann 2003). This follows a widely accepted notion that the cost of attending school for one more year is equivalent to the opportunity cost of the student's time. We employ the income based approach[10] that utilizes earnings of every working adult household member in each period to estimate human capital (Graham & Webb 1979; Jorgenson & Fraumeni 1989; Le et al. 2003) on the assumption that individual earnings are influenced by acquired skills and education level. Human capital embodied in working individuals represents the total income that can be generated in the labor market.

[9] Income reflects the consumption opportunity gained by a household within a specified time frame, and is in this study computed from the summation of (i) value of home crop production, net of cost of inputs, (ii) value of home produced livestock that were consumed, (iii) cash income from sale of livestock and livestock products, net of livestock production costs and, (iv) cash income from seasonal and monthly off-farm activities.

[10] Human capital can be measured using three closely related methods: the cost-based approach, income based approach, and educational stock based approach (Le, Gibson and Oxley 2003). The cost-or income-based measures of intangible heterogeneous labor, differs from the educational experiences measure, they are able to capture the richness of knowledge embodied in humans, and can assign monetary value to human capital stock that allows comparison with other physical capital.

The annual earnings of household adult members working in seasonal business and wage labor activities were computed from data on monthly wages and seasonal gross earnings that are also defined as sales net of seasonal costs. The annual earnings for every self-employed adult male and female individual were estimated as the marginal earning (shadow wage) as in the case of (Yang 1997; Kurosaki & Khan 2006), based on the Cobb-Douglas production function for the joint household production value in each year as indicated below:

$$\ln Q_{ht} = \alpha_0 + \beta Z_{ht} + \delta \ln L_{ht} + \lambda D_{ht}^{L} + \eta \ln I_{ht} + \eta \ln F_{ht} + \mu D_{rt} + \psi D_t + c_h + \varepsilon_{ht} \qquad (10)$$

where Q_{ht} denotes real value of total crop production in a year, Z_{ht} is a vector of household characteristics that include age of the household head, age of the household head squared, and sex of the household head, L_{ht} represents a vector of family labor force including adult male labor force, adult female labor force, and child labor force that was employed on-farm crop production, D_{ht}^{L} denotes a vector of dummy variables controls for the scarcity of each of agricultural male, female, and child labor force, I_{ht} represents a vector of other inputs including real cash expenditure on hiring labor/draft animals service, real value of seeds/planting material, and real value of fertilizer use, while F_{ht} denotes operated farm size, D_{rt} represents the three regional dummies, D_t represents year effects in form of dummy variables for time periods, c_h is the unobserved effect that is controlled for with household random effects, ε_{ht} is the error term.

Unobserved effect may be attributed to variation in land quality and differences in managerial abilities of households that have implications on their productivity. The model was estimated on a balanced panel data with household random-effects (See results in Table A.2, Appendix A), following the results of Hausman test (*chi2 = 12.69, and Prob>chi2 = 0.5511*) that failed to reject the null hypothesis that the individual household effects are random. Use of panel RE provides consistent and unbiased results and unlike in the case of fixed-effects (FE), the problem of measurement error is not exacerbated. The model assumes all factor inputs to be exogenous to the household, even when there is a possibility that such inputs can be endogenous to household production decisions.

According to Mincer (1974) and Krueger & Lindahl (2001), the Mincerian earning function specifies a linear relationship between the logarithm of earnings for individuals and the years of

schooling. The slope of this linear relationship can then be interpreted as the rate of return to investment in schooling, with time spent in school considered to be a key determinant of earnings for working age household members. We estimate the Mincerian earning function in equation (11) using unbalanced panel data of working age individuals that are above 16 years of age, and together with individual level FE estimation method.

$$\ln E_{it} = X_{it}\beta_i + V_{vt}\lambda_i + D_t\alpha_i + c_i + e_{it} \quad (11)$$

where, E_{it} denotes annual earnings for individual i working either on farm or off-farm activities in year t, X_{it} denotes a vector of individual attributes such as education level and age, V_{vt} is the vector of village level characteristics like access to education facilities, health facilities, market access, population density and agricultural potential, D_t represents dummy variables for time periods, c_i is the unobserved effect that is controlled for with individual FE or RE, and e_{it} is the error term.

Although, five alternative model specifications for equation (11) were estimated using individual FE and RE models as part of the sensitivity analysis, the main results of the computed human capital are given by the FE model specification 3* (See results in Table A.3, Appendix A). Human capital at household level was then generated by aggregating the predicted individual human capital across working adult individuals in each household. The FE model estimation is able to produce consistent parameters of the Mincerian earning function by eliminating the time-invariant individual unobserved effect c_i that creates endogeneity bias.

5.1 Model Specification

This section explains how the poverty reduction effects of changes in human capital are estimated. They represent an increase in household expenditure for every additional unit of human capital realized in household through formal schooling and on-job training of adult members amidst several idiosyncratic human capital shocks. These include the effect of unexpected incidence of deaths and illnesses, excluding pregnancy and delivery within a household. Health shocks due to sicknesses is measured as total number of days the affected household members were unable to perform their daily activities normally due to serious sickness and injury in a year.

The number of sick-days in a household is a limited dependent variable censored at zero, suggesting the need to employ a suitable econometric model (Garen 1984) that produce unbiased estimates of these health shock. However, in the spirit of (Angrist & Pischke 2009), we expect panel econometric methods to be effective in providing the best linear approximation of the embedded average statistical relationship between sick-days and household expenditure, even when the conditional expectation function (CEF) in the data may be nonlinear. Based on consumption function described in equation (9), the linear equation (12) is specified to estimate change in household welfare when human capital and idiosyncratic health shocks varies. It is then estimated using a properly specified two-stage Control Function (CF) approach that is able to control for endogeneity of human capital.

$$\ln y_{ht} = \beta_0 + \beta_1 \ln \hat{H}_{ht} + \beta_2 G_{ht} + \beta_3 \ln H\hat{S}_{ht} + \beta_4 DT_{ht} + \beta_5 \ln SK_{ht} + \beta_6 D_t + \varsigma_h + v_{ht} \qquad (12)$$

where, $\ln y_{ht}$ denotes log expenditure per adult-equivalent, $\ln \hat{H}_{ht}$ is the log of household human capital per adult-equivalent, G_{ht} the dummy variable for sex of household head, $\ln H\hat{S}_{ht}$ the log of the predicted household size in adult-equivalents that controls for potential endogeneity bias of household size, DT_{ht} denotes a dummy variable for health shocks in the form of death incidences in a year, $\ln SK_{ht}$ indicates the log of health shocks in terms of sick-days (or sick-days per adult-equivalent), D_t represents year effects that are captured by the dummy variables for time periods, ς_h denotes welfare effect due to the time-constant unobserved heterogeneity, and v_{ht} is the time-varying unobservable or omitted variable.

Human capital is considered to be endogenous to household consumption decisions and also correlated with unobservable household and community characteristics. Statistical tests were conducted to establish whether human capital and sick-days are indeed endogenous using a robustfied Durbin-Wu-Hausman (DWH) method (Cameron and Trivedi 2010). The test was conducted by regressing each of the human capital and sick-days variables on exogenous covariates in the first-stage (see results in Table A2.2, Appendix A2, p.223) using pooled OLS to generate residuals. In the second-stage, pooled OLS was again employed to regress household expenditure on the actual human capital, sick-days, death shocks, and other controls including respective residuals generated in the first-stage. Not surprisingly, the coefficient on the residual variables was found to be significant only in the specification for human capital and not for sick-days as indicated in Table A2.3 Appendix A2, p.224. This is a confirmation

that unlike, sick-days, human capital is endogenous to household consumption decisions, and would therefore require econometric methods that can effectively account for the time-invariant and time-varying heterogeneity (Vella & Verbeek 1999; Fernandez-Val & Vella 2007) to produce consistent poverty reduction estimates with true standard errors.

Hausman tests were also conducted to verify whether the use of OLS model as opposed to the standard 2SLS gives consistent parameters of sick-days. The Hausman test chi-square statistics were found to be insignificant at 2.17 with pvalue of 0.1407 for sick-days, and at 1.94 with pvalue of 0.1631 for sick-days per adult-equivalent as shown in Table A2.4, Appendix A2, p225. These test results provide further statistical evidence for not rejecting the null hypothesis that the OLS estimator is consistent for sick-days. Sick-days and death shocks variables are therefore treated to be exogenous in this study.

Instead of taking the functional forms as given in the case of equation (12), we conducted several diagnostic regression tests in form of scatter plots, nonparametric lowess and local linear regressions to verify whether there are serious nonlinearities. Plots of these specification tests are summarized in the Figures A2.1-A2.4 in Appendix A2 P.226-227, and they all show linear relationship between the log transformed household expenditure and each of the actual (or residual) log transformed human capital and sick-days variables.

The CF model is our preferred estimation method because it is able to control for the spurious correlations of omitted variable bias and is considered to be more efficient than the direct Instrumental Variable (IV) approach, but its parameters may at times become less robust (Wooldridge 2007). The CF gives reliable estimates when there are complicated correlations with nonlinearities in the data by using the residual and residual squared variable controls of the key endogenous variable of interest. According to Wooldridge (2007) a CF is able to generate precise and consistent estimates in cases where the 2SLS estimator is not.

5.2.A Two-Step Control Function (CF) Approach

A two-step control function (CF) approach is a computationally attractive and a perfect alternative to the instrumental variable 2SLS approach, but the two estimation methods have the same kind of identification conditions (Wooldridge 2007). The CF is employed to estimate parameters of equation 12, given that it is able to test and control for the presence of endogeneity bias related to the causal variable in a structural equation (Rivers & Vuong 1988;

Wooldridge 2007). Furthermore, the CF has the advantage of producing gains[11] in efficiency of parameters estimated with the standard IV method in complicated models as argued in the recent studies of Papke & Wooldridge (2008) and Ricker-Gilbert & Jayne (2009).

The CF approach allows household heterogeneity, ς_h to be correlated with exogenous variables including human capital variable, $\ln \hat{H}_{ht}$. It also assumes strict exogeneity of residuals, implying that time-varying term, v_{ht} in equation (12) can be correlated with human capital variable, but uncorrelated to the strictly exogenous variables conditional on the unobserved heterogeneity $\left(\text{i.e. } \mathrm{E}\left(v_{ht} \middle| X_{ht}, D_t, \varsigma_h\right) = 0,\ t = 1,2,3\right)$. The effect of ς_h is therefore, the reason why the v_{ht} is correlated with, $\ln \hat{H}_{ht}$ in equation 12, yet by construction, v_{ht} and, ς_h are uncorrelated. The challenge is to estimate parameters of the poverty impact equation 12, when the household ability ς_h is unobservable and the error term assumed to be uncorrelated to the human capital variable of interest. In the first-step estimation, a linear projection of the endogenous human capital variable $\ln \hat{H}_{ht}$, is specified on the exogenous variables and potential instruments as indicated in equation (13).

$$\ln \hat{H}_{ht} = \alpha_0 + \alpha_1 X_{ht} + \alpha_2 Z_{ht} + a_h + u_{ht}, \quad t = 1, ..., T \tag{13}$$

where X_{ht} denotes the strictly exogenous variables, Z_{ht} is a vector of instrumental variables that are correlated with household human capital $\left(\ln \hat{H}_{ht}\right)$, but independent of the residual variable in the outcome equation, a_h represents the unobserved household heterogeneity, and u_{ht} is the idiosyncratic error term.

The three exclusion instruments include (i) age at which the household head got married (years), (ii) age the spouse of the household head got married (years), (iii) the proportion of households that can afford at least 2 meals a day in the smallest local government (LC1). These three instruments together with the dummy variable for agricultural potential in terms of high rainfall, and distance to primary market were excluded from the second-step causal model of

[11] According to Wooldridge (2007), a control function imposes extra assumptions that are not imposed by the IV approaches, especially in nonlinear models. This makes it more efficient and more precise than the IV approach in cases with complicated models. However, a CF can be inconsistent and less robust in cases where the 2SLS estimator is consistent.

interest to ensure identification in the poverty impact equation. Agricultural potential and distance to the primary market in rural areas may influence the opportunity and ability to access to education and training that are vital for human capital accumulation. However, they are expected to have a very limited or near constant variation over short periods. This implies that their respective welfare effect in the second-stage can be time-invariant and therefore controlled for by the CF estimation.

These instruments not only vary independently of the welfare of households, but also reflect institutional constraints to investment in human capital that can account for the unobserved differences in time-varying and time-invariant heterogeneity across households. Economic literature suggests that differences in education attainment between males and females may depend on the age they chose to enter into family roles. Education attainment and age at first-marriage tend to have a strong positive correlation at the individual and society level for both sexes. This relationship can however be stronger for women who tend to marry at an early age (Marini 1978; Singh & Samara 1996) and therefore, less likely to accumulate additional human capital through further education attainment (Alexander & Reilly 1981).

Age at first-marriage can significantly be correlated with human capital accumulation in a household, given the enormous responsibility and the cost of rearing children that comes with family roles. Age at first-marriage for the household head may also determine the duration of time spent in school, implying that those that enter family roles at a later age are more likely to have attained higher levels of human capital compared to those that marry early. Furthermore, the proportion of households that afford at least 2 meals a day in the smallest local government (LC1) may reflect the general vulnerability of households in villages. We expect households in the community that is food secure to be in a reasonable position to overcome poverty traps and other potential constraints to investment in human capital. Communities with a large proportion of households that can afford at least two meals a day may on average have higher levels of household human capital endowment compared to villages with a large number of food insecure households.

In the first-step of the CF approach, equation (13) is estimated with panel household fixed-effects (FE) model to predict control function residuals. In turn, the predicted control function residuals are then included in the second-stage estimation as the additional regressor to test and control for biases due to endogeneity of the human capital variable. Allowing for panel

household FE estimation in the first-stage helps to model the incidental parameter, a_h that is eliminated through a FE type of differencing transformation. The estimating poverty impact equation in the second-step of CF is therefore specified as:

$$\begin{aligned}\ln y_{ht} = {} & \beta_0 + \beta_1 \ln \hat{H}_{ht} + \beta_2 G_{ht} + \beta_3 \ln \hat{HS}_{ht} + \beta_4 DT_{ht} + \beta_5 \ln SK_{ht} + \beta_7 D_t + \zeta \bar{X}_h + \varsigma_h \\ & + \rho_1 \hat{u}_{ht} + \rho_2 \hat{u}^2_{ht} + e_{ht}\end{aligned} \tag{14}$$

where $\bar{X}_h$, represents time-average of the strictly exogenous variables, $\hat{u}_{ht}$ denotes the CF-residuals that are derived from the panel FE estimation of the first-stage, $\hat{u}^2_{ht}$ represents the CF-residuals squared, and e_{ht} is the error term. The poverty impact equation (14) in the second-stage is estimated with pooled OLS combined with the Mundlak-Chamberlain device to unobserved effects (Rivers & Vuong 1988; Wooldridge 2007) to generate unbiased estimates. The Mundlak-Chamberlain approach to unobserved effects combines with the CF to model the time-invariant heterogeneity, ς_h by averaging-out the effect of spurious correlations conditional on time-averages of the exogenous variables and reduced form residuals as indicated in equation 15.

$$\varsigma_h = \psi + \zeta \bar{X}_h + \tau_h, \;\; \tau_h \big| X_h \sim Normal\left(0, \sigma_a^2\right) \tag{15}$$

where τ_h denotes the unobserved heterogeneity that may persist in the model but is assumed to be small enough to bias estimates. The residuals squared variable was included in the poverty impact equation to allow for greater flexibility in controlling for potential biases that result from problems of the functional forms (Wooldridge 2007). Controlling for the time-varying and time-invariant household specific unobserved effect using selectivity CF variables (Garen 1984) and valid instruments produces consistent parameters. Recall, the endogeneity of human capital comes up when the error term, u_{ht} in the first-step estimation equation (13) is correlated with, $\eta_{ht} = \varsigma_h + v_{ht}$ a vector of unobserved control variables that represent household ability and corresponding selection on observables in equation (12), such that the coefficient ρ in the linear projection of η_{ht} on u_{ht}, i.e. $\eta_{ht} = \rho u_{ht} + e_{ht}$, turns out to be statistically different from zero. Bootstrapping technique by re-sampling households and cross section units was used in the analysis to get corrected standard errors.

6. Descriptive Statistics

Table 1 presents the annual marginal (shadow) earnings for men, women, and children across households that engaged in agricultural production. The shadow earnings were derived from estimates of the Cobb-Douglas production function (see results in Table A.2, Appendix A). Table 1 shows an increase in the value of agricultural production from 2001 to 2005, with a decline in 2003. The average shadow earnings for men were double than that of women. This may be explained by the availability of abundant family labor especially for women and limited farm and off-farm employment opportunities in rural areas. Besides, this estimate does not include women's labor in household chores such as cooking and taking care of children.

Table 1
Value of farm output and average shadow earning (Ug.shs) for men, women and children based on family labor input, estimated from a Cobb-Douglas production function.

Variable	2001		2003		2005	
	Obs	Mean	Obs	Mean	Obs	Mean
Real value of total crop production (Ug.shs)	304	1002497	304	852217	304	1350546
		(1518082)		(1078144)		(1973352)
Predicted value added /total crop production (Ug.shs)	304	535013	304	593987	304	924687
		(317661)		(402310)		(813450)
Marginal/shadow earning per adult man (Ug.shs)	304	101361	304	143220	304	197593
		(75256)		(88378)		(130979)
Marginal/shadow earning per adult woman (Ug.shs)	304	51740	304	71905	304	105183
		(35179)		(45444)		(72896)
Marginal/shadow earning per child that is old enough to work (Ug.shs)	304	56394	304	49342	304	74812
		(38871)		(42752)		(66488)

Note: (i) standard errors are in parentheses, (ii) results in real values at 2005 prices; (ii) predicted value of total crop production = exp (log of predicted value of total crop production in a year), (iii) shadow earning per adult man, adult woman, and child or the marginal revenue product = [Coefficient on specific labor force variable* predicted value of total crop production]/specific labor force on farm production.

The descriptive statistics of key variables at individual and household levels are provided in Table 2. The overall average level of education is 6.38 years of schooling. Real value of annual individual earnings increased from Ug.shs 137,325 in 2001 to Ug.shs 239,544 in 2005. Average real earnings of households increased from Ug.shs 640,182 in 2001 to Ug.shs 920,524 in 2003, before reducing to Ug.shs 896,056 in 2005. The real value of human capital of households increased from Ug.shs 333,300 in 2001 to Ug.shs 486,150 in 2005, implying a growth rate of 9.2% per year. During the same period, the private real rate of return for every additional year of education increased from Ug.shs 2,288 to 3,795. The value of predicted human capital per adult-equivalent derived from the preferred panel FE model 3* in Table A.4 is found be close in magnitude to the average value of human capital per adult-equivalent generated from all the five alternative model specifications of the estimated Mincerian annual earning functions presented in Table A.4 in Appendix A.

Table 2
Summary statistics of key variables at individual member and household levels

	2001		2003		2005		Overall	
Variable description	**N**	**Mean**	**N**	**Mean**	**N**	**Mean**	**N**	**Mean**
Average age of household members (yrs) above 16 years of age	1441	33.07	1081	33.21	1116	33.13	3638	33.13
		(0.40)		(0.46)		(0.47)		(0.26)
Education years for household members above 16 years of age	1441	7.08	1081	5.86	1116	5.98	3638	6.38
		(0.09)		(0.12)		(0.11)		(0.06)
Real value of annual earnings of adult individuals (Ug.shs)	1441	137325.20	1081	276611.80	1116	239543.60	3638	210069.70
> 16 years of age		(8325.31)		(20593.87)		(16846.54)		(8717.39)
Description of household level variables								
Age of household head	304	38.56	304	45.31	304	46.93	912	43.60
		(0.66)		(0.80)		(0.77)		(0.45)
Real annual earnings aggregated at a household level (Ug.shs)	304	640182.20	304	920523.90	304	896056.00	912	818920.70
		(55934.97)		(76996.56)		(72782.77)		(40113.45)
Value of predicted human capital at household level (Ug.shs)	304	333300.10	304	397973.60	304	486150.40	912	405808.00
		(12041.12)		(15769.29)		(21137.40)		(9873.51)
Rate of returns to education across individuals (Ug.shs)	304	2288.39	304	3018.14	304	3795.24	912	3033.93
		(76.88)		(119.77)		(164.88)		(75.33)
Mean predicted human capital per adult-equivalent /10000,	304	4.69	304	7.11	304	8.16	912	6.65
across the estimated 5 models (1-5) of Mincerian earning functions		(0.09)		(0.16)		(0.21)		(0.10)
Predicted real value of human capital per adult-equivalent/10000	304	4.47	304	6.77	304	7.93	912	6.39
(Ug.shs) derived from FE model 3 of the Mincerian earning function.		(0.09)		(0.16)		(0.19)		(0.10)
Household income per adult-equivalent (Ug.shs)		215867.70		340107.20		376952.70		310975.90
	304	(17511.47)	304	(29103.48)	304	(24767.04)	912	(14181.79)
Household expenditure per adult equivalent (Ug.shs)		346208.60		379741.80		385244.30		370398.20
	304	(15208.79)	304	(38128.95)	304	(20421.81)	912	(15277.07)
Members of the household that passed away (died) in a year	98	0.88	98	0.44	98	0.39	294	0.57
		(0.10)		(0.08)		(0.06)		(0.05)
Number of days sick individuals were unable to work normally			304	55.63	304	38.91	608	47.27
				(4.74)		(3.72)		(3.03)
Number of sick days per adult-equivalent			304	10.74	304	8.03	608	9.39
				(0.89)		(0.82)		(0.61)

Note: (i) Standard errors are in parentheses; (ii) monetary values in real terms (2005 value)

Turning to welfare indicators, Table 2 (above) reveals a steady increase in household income and expenditure per adult-equivalent in a period of 5 years. Household real income per adult-equivalent increased from Ug.shs 215,868 in 2001 to Ug.shs 376,953 in 2005. During the same period, household expenditure per adult-equivalent increased from Ug.shs 346,209 in 2001 to Ug.shs 385,244 in 2005. As pointed out before, the difference in the rate of change in income and can be attributed to data quality in case of income variable, and household consumption smoothing. Health shocks in terms of death incidences were reported in 32% of the households. Notice that twice as many people (0.88) passed away in 2001 compared to 0.44 persons and 0.39 persons in 2003 and 2005 respectively. The average number of sick-days also reduced from 55.63 in 2003 to 38.91 in 2005, which translates to a reduction from 10.74 to 8.03 sick-days per adult-equivalent.

7. Estimation Results and Discussion

This section reports regression estimates on the poverty reducing impact of investment in human capital through education and related training in rural areas of Uganda. In order to control for the problem of endogeneity, we first estimated determinants of human capital to generate predicted CF-residuals. Results of this first-stage CF regression using the household panel FE are reported in Table 3. Notice, model 1 includes only the effects of health shocks that are captured by a dummy variable for deaths in a household. Conversely, models 2 and 3 capture the effects of both death and sickness health shocks. Sick-days (and sick-days per adult-equivalent) were reported in the data for only two periods (2003 and 2005) of the three periods. In all these model specifications in Table 3, variables maintain similar signs, with coefficients that vary slightly in magnitude and levels of significance. The p-values of Wald chi2 statistic in each model are significant at 1%, implying strong joint effect of the specified model covariates in explaining variation in household human capital.

Table 3
Results of the first-step FE estimation of log of human capital and log health shocks

	Log human capital per adult-equivalent/10000 (Ug.shs)		
	2001-05	2003-05	
Independent variables	1	2	3
Sex of the household head (1 = Male, 0 = Female)	0.110	0.273	0.275
	(0.07)	(0.28)	(0.28)
Dummy for deaths in a year (1 = household lost a person, 0 otherwise)	0.135***	0.137**	0.136**
	(0.05)	(0.06)	(0.06)
Log of predicted household size in adult-equivalent	-0.652***	-0.294	-0.307
	(0.22)	(0.26)	(0.25)
Age household head got married (yrs)	0.003	-0.020**	-0.019**
	(0.00)	(0.01)	(0.01)
Age the spouse of the household head got married (years)	0.137*	0.082	0.071
	(0.07)	(0.10)	(0.10)
Proportion of households that can afford at least 2 meals a day in the LC1	0.113*	0.043	0.045
	(0.06)	(0.06)	(0.05)
Distance to primary market (miles)	-0.006	0.002	0.002
	(0.01)	(0.01)	(0.02)
Dummy variable for high rainfall (1= Bi and Uni high, 0= otherwise)	0.074*		
	(0.04)		
Dummy variable for year 2001	-0.346***		
	(0.07)		
Dummy variable for year 2003	-0.167***	-0.155***	-0.161***
	(0.02)	(0.02)	(0.02)
Log actual days, sick household members were unable to work		0.006	
		(0.01)	
Mean log sick-days per adult-equivalent, unable to work			0.022
			(0.02)
Constant	0.009	1.049	1.252
	(1.51)	(2.18)	(2.08)
Household fixed effects	Yes	Yes	Yes
Number of observations	912	608	608
Number of households	304	304	304
Wald chi2	427.084	85.024	86.791
Prob > chi2	0.000	0.000	0.000
R2-within	0.453	0.209	0.213
R2-between	0.007	0.022	0.024
R2-overall	0.029	0.027	0.031
Panel-level standard deviation (sigma_u)	1.038	0.568	0.513
Standard deviation of error term (sigma_e)	0.321	0.240	0.240
Panel fraction of variance (rho)	0.913	0.848	0.821

Note: Bootstrap (399) replications) standard errors are in parentheses. * Significant at 10%; ** significant at 5%; *** significant at 1%

Table 4 reports the impact of changes in human capital and health shocks on household expenditure per adult-equivalent based on the estimated second-step of the CF approach. It can be seen that the estimated coefficients on the log of human capital variable are positive and

significantly different from zero at 1-10% level in all the 6 model specifications. This is strong evidence that access to human capital is a key determinant of household welfare in rural Uganda. It is also important to note that these coefficients can be interpreted in form of elasticity. In case of models 1 and 4, the coefficients range between 0.413-0.432 suggesting that the approximate relative rate of increase in household expenditure per adult-equivalent is of 41.3 - 43.2% of a relative rate of increase in human capital stock. The impact of human capital is observed to decrease slightly when the effect of health shocks in terms of sick-days is controlled for as shown in the rest of the model specifications in Table 4 that relies on data for only two periods of 2003 and 2005. The coefficients in these model specifications indicate that varying human capital by 1 unit enhances household expenditure per adult-equivalent by 0.27-0.32 percent holding other factors constant. Whether we estimated the models without and with the CF-residuals squared, parameter estimates did not change significantly, implying robust results on human capital and health shock variables.

Estimates in Table 4 further show the impact of idiosyncratic health shock to human capital that include the number of sick-days household members spent at home unable to work normally due to the effect of sickness. The coefficients on both "sick-days" and "sick-days per adult-equivalent" appear to be small in magnitude and statistically insignificant. We do not find strong evidence in these data therefore, that health shocks in terms of sicknesses affect household welfare. Household consumption welfare appears not to be very responsive to the variation in idiosyncratic health shocks to human capital and this may indicate the underlying ability to smooth consumption. This finding is obviously against our hypothesis that a household may experience severe output losses when its members experience sicknesses that compels them to spend quite some time at home waiting to recover. Perhaps, households have alternative informal insurance mechanisms that are able to effectively mitigate the effects of such unexpected health risks. These may include the ability to engage in local mutual social networks such as the help of relatives, neighbors and self-help community groups that can provide cheap insurance against such shocks in ways that enable adequate consumption smoothing especially in risky times.

Conversely, the impact of death shocks in rural households is found to be negative and insignificantly different from zero in all 6 model specifications. And while death shocks are expected to be more serious and to have short-term as well as long-term negative effects on household consumption, we find the opposite.

Table 4
Results of the CF approach for welfare estimates of human capital and health shocks, a pooled OLS model estimation

	Log of real household expenditure per adult-equivalent /10,000 (Ug.shs)					
	With CF residuals only			With CF residuals & CF residuals squared		
	2001-05	2003-05		2001-05	2003-05	
Independent variables	1	2	3	4	5	6
Log human capital per adult-equivalent/10000 (Ug.shs)	0.432***	0.319**	0.322**	0.413***	0.273**	0.278*
	(0.09)	(0.13)	(0.14)	(0.10)	(0.13)	(0.14)
Log actual days, sick household members were unable to work		0.016			0.016	
		(0.04)			(0.04)	
Log sick-days per adult-equivalent, unable to work			0.071			0.071
			(0.05)			(0.05)
Sex of the household head (1 = Male, 0 = Female)	0.195*	0.294**	0.300**	0.205**	0.355***	0.365***
	(0.11)	(0.13)	(0.13)	(0.10)	(0.13)	(0.14)
Dummy for deaths in a year (1 = household lost a person, 0 otherwise)	-0.060	-0.112	-0.121	-0.057	-0.104	-0.110
	(0.07)	(0.10)	(0.10)	(0.07)	(0.10)	(0.10)
Log of predicted household size in adult-equivalent	-0.173	0.167	0.155	-0.180	0.197	0.189
	(0.42)	(0.49)	(0.51)	(0.41)	(0.54)	(0.51)
Mean log human capital per adult-equivalent/10000 (Ug.shs)	0.143	0.539***	0.551***	0.144	0.544***	0.553***
	(0.13)	(0.18)	(0.18)	(0.12)	(0.17)	(0.18)
Mean log predicted household size in adult-equivalent	-0.276	-0.520	-0.512	-0.267	-0.577	-0.568
	(0.45)	(0.52)	(0.54)	(0.43)	(0.58)	(0.56)
Mean log actual days, sick household members were unable to work		-0.043			-0.033	
		(0.07)			(0.07)	
Mean log sick-days per adult-equivalent, unable to work			-0.100			-0.091
			(0.09)			(0.09)
CF-residuals (derived from panel FE model in the 1st stage)	-0.003	-0.079	-0.094	0.016	-0.030	-0.045
	(0.02)	(0.07)	(0.08)	(0.04)	(0.07)	(0.08)
CF-residuals squared (derived from panel FE model in the 1st stage)				0.011	0.106*	0.142*
				(0.02)	(0.06)	(0.07)
Dummy variable for year 2001	0.191*			0.182*		
	(0.10)			(0.10)		
Dummy variable for year 2003	-0.042	-0.058	-0.078	-0.045	-0.063	-0.083
	(0.06)	(0.07)	(0.07)	(0.06)	(0.07)	(0.06)

Constant	2.893***	2.228***	2.168***	2.904***	2.246***	2.179***
	(0.37)	(0.49)	(0.51)	(0.36)	(0.49)	(0.49)
Number of observations	912	608	608	912	608	608
Wald chi2	76.241	66.346	65.488	70.604	76.231	68.063
Prob > chi2	0.000	0.000	0.000	0.000	0.000	0.000
R-squared	0.086	0.116	0.119	0.086	0.121	0.125
Root Mean Square Error (MSE)	0.704	0.710	0.709	0.704	0.709	0.707

Note: Bootstrap (399) replications) standard errors are in parentheses. * Significant at 10%; ** significant at 5%; *** significant at 1%

Households that loose at least one member in a year are more likely to experience a decrease in their expenditure per adult-equivalent of between 5.7-12.1 percent, but this is clearly insignificant. The prevalence multiple shocks at the household and community level can have negative effects on household welfare including forcing a substantial number of households to descend into poverty (Lawson et al. 2006). The dummy variable for the sex of the household head was included to control for the effects of gender differences in decision making, while the log of predicted household size[36] in adult-equivalent is meant to control for the potential endogeneity bias of the consumer units in household. Dummy variables for year periods control for universal time-specific shocks and were found to be positive and significant for 2001, but insignificant and negative for 2003. The predicted CF residuals for time-varying unobservable, also derived from the first-stage panel FE regression of human capital is not statistically significant at standard levels, indicating that biases due to correlations with unobserved heterogeneity have been well controlled for (Rivers & Vuong 1988; Wooldridge 2002; Wooldridge 2007) to generate consistent coefficients.

The coefficient on the CF-residual variable squared is significant at 10 percent in models 5 and 6, implying a limited presence of non-linear functional forms that are also controlled for by the same squared CF-residual variable. The poverty impact equation (12) was also estimated with the standard Instrumental Variable (IV) two-stage least squares (2SLS) approach to assess the robustness of the key CF results. Whether we employed a CF or the standard Instrumental Variable 2SLS and G2SLS panel RE model estimation, poverty reduction estimates of variation in human capital and health shocks did not change significantly. However, the estimates derived from the CF were found to be more efficient compared to estimates generated by the IV[37]approach. A further robustness check of the main results estimated the biased poverty reduction estimates for the endogenous human capital and health shocks using a simple OLS model. Results are presented in Table A.1 in the appendix A, and clearly show very significant and larger positive coefficients (0.5-0.55) on human capital variable, and insignificant but similar coefficients on health shock variables for deaths and sick-days. This is a further confirmation that our CF results are robust and precise, despite using instruments that not very strong including some with limited variability across time.

[36] Panel random-effects model was used to estimate the log of household adult-equivalents as indicated in Table A2.1 in appendix A2, p.222). The predicted log of household adult-equivalent is then employed as a control variable of household size in the poverty impact equation.

[37] Results for the standard IV estimation are not reported, but can be accessed from authors upon request.

8. Conclusion

In this article, we have employed the income approach to compute the value of household human capital. A Mincerian earning function at individual level was estimated to calibrate returns to human capital investments in form of years of formal schooling and access to on-job training for working adult household members. The impacts of changes in human capital endowment and health shocks to human capital on household expenditure per adult equivalent were estimated using a micro panel data of 304 rural Ugandan households surveyed in 2001, 2003, and 2005, and a two-step control function approach combined with the Mundlak-Chamberlain device to unobserved effects.

Empirical findings show strong positive and significant poverty reducing impact of increased accumulation of human capital through investment in education and on-job training of household members across rural households. Households with more educated and skillful members are shown to gain higher welfare improving effect after we have controlled for endogeneity of human capital and other control variables that affect human capital gain and loss. The low levels of human capital in rural areas of Uganda have made investment in education an imperative poverty reducing instrument. The findings further show a negative and insignificant effect of health shocks to human capital in terms of unexpected death incidence. This suggests that the prevailing local institutional arrangements may be strong enough to provide affordable informal insurance to meet the cost of funerals and related activities in case a household looses a member. The prevalence of sicknesses was found to have insignificant effects on household consumption expenditure per adult-equivalent. This can be attributed to the prevailing strong family networks and other informal insurance mechanisms that possibly play a significant role in helping the affected households to smooth the effects of these health shocks.

The major policy implication of our findings is to support the relevance of the on-going public and universal education, and access to training programs. This requires interventions that can reduce the cost of schooling, increase the level of enrollment, and improve the quality of training in primary, secondary, and technical levels of education. The provision of access to affordable health insurance in rural areas is also crucial if the poverty reduction effects of human capital, and human capital gain is to be consolidated. These results provide additional welfare-based arguments for engaging rural households and relevant informal community-based organizations to development programs that promote access to affordable public education and health services.

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Appendix A

Table A.1
Results of the OLS estimation of the welfare effects of change in human capital & health shocks

	Log of real household expenditure per adult-equivalent /10,000 (Ug.shs)		
	2001-05	2003-05	
Independent variables	1	2	3
Log human capital per adult-equivalent/10000 (Ug.shs)	0.500***	0.546***	0.539***
	(0.07)	(0.09)	(0.08)
Log actual days, sick household members were unable to work		-0.004	
		(0.02)	
Log sick-days per adult-equivalent, unable to work			0.030
			(0.03)
Sex of the household head (1 = Male, 0 = Female)	0.193*	0.237*	0.250*
	(0.10)	(0.13)	(0.13)
Dummy for deaths in a year (1 = household lost a person, 0 otherwise)	-0.049	-0.083	-0.090
	(0.07)	(0.09)	(0.10)
Log of predicted household size in adult-equivalent	-0.420**	-0.320	-0.314
	(0.17)	(0.20)	(0.21)
Dummy variable for year 2001	0.276***		
	(0.07)		
Dummy variable for year 2003	-0.040	-0.028	-0.044
	(0.06)	(0.06)	(0.06)
Constant	2.944***	2.654***	2.589***
	(0.32)	(0.41)	(0.41)
Number of observations	912	608	608
Wald chi2			
Prob > F	0.000	0.000	0.000
R-squared	0.084	0.100	0.102
Adjust R-squared	0.078	0.092	0.093
Root MSE	0.703	0.714	0.713

Note: Bootstrap (399) replications) standard errors are in parentheses. * Significant at 10%; ** significant at 5%; *** significant at 1%

Table A.2
Estimation of the Cobb-Douglas production function, with panel random-effects model to derive shadow earnings for household adult members that are self-employed on farm

	Log of real value of total crop production (Ug.shs) in a year (Value added)		
Independent variables	b	se	Xmfx_dydx
Age of the household head (yrs)	0.008	(0.017)	0.008
Age of the household head (yrs) squared	-0.000	(0.000)	-0.000
Sex of the household head (Male =1 Female = 0)	0.051	(0.131)	0.051
Log of male labor force on-farm crop production	0.308***	(0.103)	0.308
Log of female labor force on-farm crop production	0.177	(0.124)	0.177
Log of child labor force on-farm crop production	0.267***	(0.088)	0.267
Dummy for on-farm male labor force 1= low/scarce, 0=otherwise	0.301**	(0.129)	0.301
Dummy for on-farm female labor force 1= low/scarce, 0= otherwise	-0.024	(0.122)	-0.024
Dummy for on-farm child labor force 1= low/scarce, 0=otherwise	0.049	(0.109)	0.049
Log of real expenditure on hired labor & draft animal service (Ug.shs)	0.039***	(0.008)	0.039
Log of real value of seeds/planting material a year (Ug.shs)	-0.003	(0.008)	-0.003
Log of real value of fertilizer use in a year (Ug.shs)	0.040***	(0.014)	0.040
Log of farm size (acres)	0.468***	(0.050)	0.468
Dummy variable for region2 (Eastern Uganda)	-0.005	(0.087)	-0.005
Dummy variable for region3 (Western Uganda)	0.110	(0.101)	0.110
Dummy variable for year 2001	-0.844***	(0.130)	-0.844
Dummy variable for year 2003	-0.290***	(0.062)	-0.290
Constant	11.648***	(0.528)	
Household random effects	YES		
Number of observations	912		
Number of households	304		
Chi2 statistic	337.477		
Prob > chi2	0.000		
R2-within	0.245		
R2-between	0.379		
R2-overall	0.303		
Panel-level standard deviation	0.332		
Standard deviation of error term	0.968		
Rho (Panel fraction of variance)	0.106		
Hausman test statistic (Prob>chi2 = 0.5511)	12.69		

Note: (i) Bootstrap (399 replications) standard errors are in parentheses. * Significant at 10%; ** significant at 5%; *** significant at 1% , (ii) The Cob-Douglas production estimated with the random-effects panel method, after a Hausman test failed to reject the null-hypothesis.

Table A.3 Results of the estimated Mincer annual earning function of adult individuals

	Log of real annual individual earnings (lnyrearn)				
	2001-2005			2003-2005	
Independent variables	1	2	**3***	4	5
Education/schooling years	0.027***	0.031***	0.049***	0.036***	0.025
	(0.01)	(0.01)	(0.01)	(0.01)	(0.02)
Age of adult individuals	0.064***	0.065***	0.029***	0.080***	0.031
	(0.01)	(0.01)	(0.01)	(0.01)	(0.02)
Age of adult individuals squared	-0.001***	-0.001***	-0.000***	-0.001***	-0.000
	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
Sex of household members (1= male, 0 = Female)	0.749***	0.741***	0.539***	0.752***	0.652***
	(0.04)	(0.04)	(0.09)	(0.05)	(0.20)
Dummy variable for year 2001	-0.569***	-0.605***	-0.661***		
	(0.04)	(0.04)	(0.05)		
Dummy variable for year 2003	-0.118***	-0.114***	-0.155***	-0.063	-0.203**
	(0.03)	(0.03)	(0.04)	(0.07)	(0.10)
Dummy variable for population density (1 =high, 0= otherwise)		-0.084**			
		(0.04)			
Dummy variable for market access (1=high, 0= otherwise)		0.069*			
		(0.04)			
Dummy variable for agricultural potential (1= high rainfall, 0 =otherwise)		-0.164***			
		(0.03)			
Population density/square km				-0.000	0.000
				(0.00)	(0.00)
Dummy for access to primary schools in the LC1 (1= present, 0= otherwise)				0.120**	-0.132
				(0.06)	(0.10)
Distance (miles) to the nearest primary school				0.014	0.026
				(0.02)	(0.02)
Dummy for access to secondary schools in the LC1 (1= present, 0= otherwise)				0.004	0.129
				(0.10)	(0.20)
Distance (miles) to the nearest secondary school				0.006	-0.019
				(0.01)	(0.02)
Number of primary schools (public and private) operating in the LC1				-0.100**	-0.155**
				(0.04)	(0.08)
Number of secondary schools (public/private) operating in the LC1				0.095	-0.141
				(0.06)	(0.17)
Dummy for presence of a local dispensary/clinic in the LC1 (1 = present, 0 = otherwise)				0.057	0.052
				(0.07)	(0.10)
Distance (miles) to the nearest local dispensary or clinic				-0.006	-0.006*
				(0.00)	(0.00)
Constant	9.948***	10.029***	10.731***	9.484***	10.979***
	(0.11)	(0.11)	(0.22)	(0.17)	(0.58)
Individual Random-Effects	YES	YES	NO	YES	NO
Individual Fixed-Effects	NO	NO	YES	NO	YES
Number of observations	3616	3616	3616	2106	2106
Number of individuals	2012	2012	2012	1312	1312
Chi2 statistic	830.171	915.988	256.158	540.843	100.098
Prob > chi2	0.000	0.000	0.000	0.000	0.000
R2-within	0.141	0.140	0.162	0.045	0.068
R2-between	0.238	0.250	0.164	0.268	0.103
R2-overall	0.227	0.235	0.169	0.236	0.098
Panel-level standard deviation	0.375	0.362	0.860	0.569	0.976
Standard deviation of error term	0.867	0.866	0.867	0.756	0.756
Rho (Panel fraction of variance)	0.157	0.149	0.496	0.361	0.625

Note: (i) Bootstrap (399) replications) standard errors are in parentheses. * Significant at 10%; ** significant at 5%; *** significant at 1%. (ii) Human capital variable was computed based on results of estimated model **3*.**

Paper III

Children and Household Welfare: Evidence from Rural Uganda

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ABSTRACT. *Children can generate immediate benefits in form of cash income or otherwise to their parents when allowed to supply labor in productive activities. This may however, exacerbate household poverty levels over-time. The objective of this article is to assess the effect of the variation in the number and adult-equivalent of young children (below 10 years of age) on household expenditure per adult-equivalent in rural Uganda. The study utilises a micro panel data set of 304 households surveyed in 2001, 2003, and 2005. Non-parametric smoothing technique of locally weighted regression and econometric panel models were employed to control for the unobserved household heterogeneity and endogeneity of children. The results provide evidence of a small negative and insignificant poverty impact of larger number and adult-equivalent of children. This suggests that young children in rural Uganda to a limited extent engage in productive activities, contrary to popular views about "child labour on farms". Improved access to education through the on-going national programs of universal primary, secondary, and adult-literacy education may have lead to prioritization of building human capital. Policy measures that can further improve the level of education and health can be effective in alleviating child labour and poverty across rural households. (JEL J24, J13, O12 and I31)*

Key words: Endogeneity, young children, unobserved heterogeneity, poverty impacts.

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I. Introduction

This paper assesses the role of children as an investment good to families in rural Uganda, a country with one of the fastest growing populations in Africa. And while the growth poses significant challenge to development, it can also be turned into an opportunity through investment in good education and health (human capital) to reap the demographic dividend (World Bank 2010). A demographic dividend refers to a hump in economic returns in the form of increased savings, investment, and efficiency of resource use. This economic transition is created by a shift from a population structure with high fertility, high mortality, and a small share of working age population (between 15- 64 years) to one with low fertility, low mortality, and a large share of working age adults (Ashford 2007; Bloom et al. 2007) and high empoyment opportunities.

The majority of rural households in Uganda engage in agricultural production. They are faced with imperfect and missing factor markets including that of insurance to health shocks and other disasters. The presence of imperfect labour markets, thin financial markets, weak local institutions for social security, and the lack of public pension schemes can have far reaching implications for labour supply and production processes, and this makes children a valuable asset in a household (Ray 1998; Angemi 2002). The need to manage income risk effectively especially in the old age may compel parents to have many children. Children can generate immediate benefits in form of cash income or otherwise, when they engage in useful economic activities of subsistence production, small businesses and domestic work.

In Uganda, the elimination of school fees under the Universal Primary and Secondary Education reduced the cost of child education and increased the likelihood of boys and girls to attend school before the age of 8 years by 10% (Grogan 2006; Grogan 2009). This increase in school enrolment is expected to increase human capital and to reduce child labour in rural Uganda, where a substantial proportion (34.2%) of households lives below the poverty line (UBOS 2006; Ministry of Finance Planning and Economic Development 2010). Whether this public investment in education can stimulate a significant reduction in the short-term benefits that poor farm households derive from their children is an empirical question that this study attempts to examine. Human capital is defined as purchasing power for all adult-working members in the household that signify current earnings plus the expected present value of future earnings (Hall 1978). Human capital therefore refers to improvements in such factors as; formal education level, literacy, knowledge, skills, competencies, attributes, nutrition, health and

experience that can improve the technical and allocative efficiency of labor input in terms of quality, future productivity, and income advantage (Black & Lynch 1996; Ray 1998; Bardhan & Udry 1999; Jolliffe 2002; Kurosaki & Khan 2006).

The level of consumption per adult-equivalent (welfare) can reduce when a household opts to have more children for a given level of expenditure and household size. It can also increase when adult household members choose to work more. Arguably, the impact of children on household productivity and expected future income may be determined by two effects: first, the extent to which child labour is allowed to substitute the labour input of adult household members in the production process, and second, the amount (either less or more) of current resources a household commits to investments in good health and education of household members including children.

Children contribute to the human capital accumulation of the household in the medium and long term, and play a crucial role in the retirement planning of their parents (Cigno et al. 2002; Scholz & Seshadri 2007). Households choose to invest in the number and quality of children to increase the expected future income. In a life cycle perspective, parents can opt to invest less (or more) in their children now by using more (or less) of the expected future income. However, the benefits of having high quality children are balanced against the cost of child-rearing in terms of parental expenditure on food, clothing, schooling and other requirements. These costs suggest a negative impact of children on the household per capita consumption (Becker & Barro 1986) and may encourage families to have few children.

This article estimates the poverty reduction impact of own and fostered young children on household welfare in rural Uganda. Specifically, the article (i) measures the impact of the variation in the absolute (number) and the adult-equivalent of the number of young children below ten years of age on household welfare, and (ii) examines the distribution of children endowment across households of different welfare levels, and how they interact with adult human capital asset to influence household welfare. Household welfare is measured in terms of real expenditure per adult-equivalent. Understanding the welfare effects of children is imperative in guiding policy interventions that: control fertility levels, provide effective child care, support families with good health care, reduce child participation in labour force, promote education attainment, and ensure subsequent poverty eradication in the country.

We expect children in a household to be endogenous and correlated with unobserved household and community characteristics. This creates substantial methodological challenges in revealing the unbiased estimates of their respective welfare effects. There are also concerns that the lack of suitable instruments to predict the endogenous variable of children may compromise the estimated IV results, given the requirement that the instruments should be exogenous and uncorrelated with error term on the outcome equation. The study therefore, employs a first-differencing (FD) method as the preferred estimation approach and a new residual component (RC) method based on Holden et al. (2009), as the robustness check. The two methods are effective in controlling for biases due to the limited endogeneity of children and unobserved household heterogeneity.

Key study findings reveal that poor households in rural Uganda have more young children below ten years of age than is the case with the relatively better-off households. The number of children appears to decrease with an increase in the level of education and health of adult members of the household. Households with a large number and adult-equivalent of young children are shown to experience small negative and significant short-term welfare effects, which clearly become insignificant after controlling for the effects of household investment in adult-human capital and differences in child endowments across households. This suggests that young children in rural Uganda engage in productive activities to a limited extent, contrary to popular views about short-term economic benefits of "child labour on farms". A reduction in the cost of child education and improved access to education through the on-going national programs of universal primary, secondary, and adult-literacy education may have lead to prioritization of building human capital.

The paper is organized as follows. In section 2, the extended introduction based on the review of relevant economic literature on child endowment and household welfare is discussed. Section 3 presents a conceptual framework of investment in children. Data and measures of welfare are discussed in section 4. Details of the econometric model specification and estimation are given in section 5. Section 6 presents results including descriptive statistics and discussion. Results and discussion of the econometric analyses are presented in section 7. Section 8 concludes.

II. Children and Household Welfare

This section provides a review of relevant economic literature on the relationship between children on household welfare. Empirical evidence on asset-based risk coping strategies under borrowing constraints shows that income of rural agricultural households can be susceptible to great uncertainty due to shocks (Deaton 1990; Deaton 1991; Deaton 1992; Blundell et al. 1994; Attanasio & Weber 2010). This may lead to widespread low returns to assets and high levels of poverty. As a result, families may opt to have a large number of children as a strategy to cope with the anticipated income and death shocks in the future, a rational behaviour that is in contention with the Malthusian theory.

Contrary to the insurance argument, Malthusian theory emphasizes the importance of high household income in determining the desire of parents to have many children (and the ability to raise them). However, poor and rich households in developing countries can have many children and can enjoy scale economies in consumption irrespective of income status. Distinctively, large land holdings create incentives for rural asset-rich households to demand more children, a phenomenon that Bhalotra and Heady (2003) calls the "wealth paradox". Here, altruistic asset-rich parents understand that children are better-off specializing on schooling than engaging in work activities. They find it rational to send their children to work only when their income falls below certain critical level.

Poor parents that are willing to pay a low maximum price (low shadow price) per child may choose to have many children with low investment in their children's education. Conversely, the high-income families can choose to have low fertility rates with high investment in education (Rosenzweig 1990; Angemi 2002; Moav 2005; Cockburn & Dostie 2007). This can change the relative supply of skilled workers by age group and education attainment that is crucial for poverty reduction over time.

There several other reasons that might compel parents to opt for child work as opposed to schooling. For example, differences in returns to school and returns to child labour can encourage children in land-poor households to work rather than attend school (Bhalotra & Heady 2003; Cockburn & Dostie 2007). Such differences can be enhanced by access to more productive assets and higher use of capital equipment that tend to raise the productivity of child labour. Similarly, access to micro-credit may increase the productivity of household assets and children's propensity to work, especially during the season of peak labour demand (Hazarika &

Sarangi 2008). The supply of child labour may also depend on the perceived subsistence level of household income without child labour, below which families are prompted to let their children to work in a way that matches the "luxury axiom" (Edmonds & Schady 2009). The luxury axiom states that households have some perceived level of subsistence without child labour, below which parents may choose to have child labour irrespective of the child's potential economic contribution. Intervention that can support households from sliding below the subsistence level of income can therefore reduce child labour. For instance, Edmonds and Schady (2009) shows that the allocation of a small financial transfer of $15 per month to eligible mothers can reduce child labour significantly. This is true whether the size of money transfer is too small to cover the foregone earnings or otherwise.

There is also a problem of orphans that is reported to be widespread throughout Uganda, due to deaths created by various fatal diseases including AIDS and other health shocks (Ntozi 1997). To date, almost all orphans in Uganda are cared for by their extended family members who bear the burden and the cost of child rearing. A recent study in Uganda shows that taking in one foster child or an additional own child below 14 years of age may have significant reduction on overall household welfare especially among the poor (Deininger et al. 2005). The study shows that household consumption is reduced by 3.2% for every additional foster child that is taken in, compared to 0.72% decrease in household consumption for every additional own child. These estimates appear to represent a lower bound of the true impact, given that the estimation method employed did not control for endogeneity bias of children. Another recent study, Ganglmair (2006) points out that boys in rural Uganda combine their labour activities with school attendance, while girls tend to specialize. This is blamed on gender bias in the implementation of domestic household activities.

III. Conceptual Framework of Household Investment in Children and Consumption

The standard life cycle suggests that households smooth their consumption across periods of high and low income to keep expected marginal utility constant (Hall 1978). Thus, prudent households can delay consumption until uncertainty about the future is resolved (Ludvigson & Paxson 2001), while the presence of precautionary motive may limit households from consuming out of the uncertain income in order to reduce future consumption uncertainty . Similarly, families may choose to have unique demographic structure that is crucial in explaining the growth of consumption over a household's life cycle. Attanasio & Weber (2010)

shows how demographics play an important role in the variation of consumption with age, especially in pre-retirement years.

Assume that parents allocate expenditure intertemporally to maintain their marginal utility of expenditure constant from period to period. Household characteristics determine the nonseparability in preferences over consumption and labour supply and also the excess sensitivity between growth in consumption and income (Blundell et al. 1994; Attanasio & Browning 1995; Attanasio et al. 1999; Fernández-Villaverde & Krueger 2007; Browning & Ejrnæs 2009). Non-reparability between consumption and labour supply implies the tendency of household consumption of market goods to track the increase in labour supply (or wage rate) over the life cycle. In this article, we adopt the model of Browning & Ejrnæs (2009) to measure the impact of children on the household's marginal utility of consumption by assuming away any direct non-linear age effects due to liquidity constraints and prudence on household utility. Browning and Ejrnæs (2009) employed a similar model on the time series data of the cross-section family expenditure to explain how the often-observed hump shape between consumption and income, may be explained by taking a proper account of the number and ages of children. Most previous investigators make arguments in favor of the presence of liquidity constraints, a precautionary motive, non-separability between consumption and labor supply, and the path of demographics over the life-cycle that may instead explain this high life-cycle correlation between consumption and income.[1]

The model assumes that households have at least one child[2], whose effect on consumption is independent of age. Let n_{ht} be the number of young children in household h at age t. Assume also that the within-period utility function is independent of age, conditional on number of children such that:

$$u_{ht} = u^h\left(C_{ht}, n_{ht}\right) \tag{1}$$

where C_{ht} is the consumption of the household h at age t. The utility function is able to capture the welfare (utility) effects of children age in a household, and can have a functional form of the following variant:

$$u^h\left(C, n\right) = v_h\left(Ce^{-\delta_h n}\right)e^{\delta_h n} \tag{2}$$

[1] This correlation is also critical for aggregate saving and economic growth.

[2] The effects of differences in parental preferences (common set of preferences assumed), spacing and gender of children involved are ignored.

where $v_h(.)$ is strictly increasing and strictly concave. In order to derive the Euler equation, we adopt a demographic separability restriction as explained in demand literature (Browning 1992), to incorporate the welfare effects of children that make households worse-off or otherwise. For example, unbiased estimates of demand or consumption are derived when the effects of children are conditioned on household labour supply. The Euler equation is an important instrument to analyze consumption, to estimate preference parameters and to test the over identifying restrictions implied by the consumers' optimization problem (Attanasio 1999). Assume also that the household face uncertainty and employs a discount factor $\delta_h = 1/1-\rho$ (a constant between zero and one) to discount next period's utility, with the utility discount rate $\rho = r$ the real rate; that is, the nominal interest rate of return minus inflation rate.

The Euler equation gives:

$$u_C^h(C_{ht}, n_{ht}) = u_C^h(C_{ht+1}, n_{ht+1})$$

Such that:

$$v_h^{'}\left(C_t e^{-\delta_h n_{ht}}\right) = v_h^{'}\left(C_{t+1} e^{-\delta_h n_{h,t+1}}\right) \tag{3}$$

Thus:

$$\Delta c_{ht+1} = \delta_h \Delta n_{ht+1}$$

where the lower case c_{ht} denotes log of, C_{ht}, $e^{-\delta_h n_{ht}}$ denotes a child response function of change in consumption that keeps the marginal parental utility of expenditure constant over changes in the state of a child. Parents are expected to increase their expenditure $(\delta_{ht} > 0)$ during periods when children are present at home compared to periods when they are away. Therefore, equation (3) implies that changes in consumption are proportional to changes in the number and state of children.

Assume the isoelastic form of the sub-utility function:

$$v_h\left(Ce^{-\delta_h n}\right) = \frac{\left(Ce^{-\delta_h n}\right)^{(1-\theta_h)}}{(1-\theta_h)} \tag{4}$$

Use of strong assumptions on the nature of uncertainty and preferences either in form of quadratic or isoelastic preferences can be reliable in deriving an analytical solution for the level

of consumption (Attanasio, 1999). Furthermore, assuming a constant real interest rate[3], r and a discount factor, β_h and no liquidity constraint, the exact Euler equation becomes:

$$\left(C_{ht}e^{-\delta_h n_{ht}}\right)^{-\theta_h} = \beta_h\left(1+r\right)E_t\left[\left(C_{ht+1}e^{-\delta_h n_{ht+1}}\right)^{-\theta_h}\right] \quad (5)$$

A linearised version of the above Euler equation is adopted to be estimated on the panel data as:

$$\Delta c_{ht+1} = \alpha_h + \delta_h \Delta n_{ht+1} + \varepsilon_{ht+1} \text{ with } \mathrm{E}_t\left[\varepsilon_{ht+1}\right] = 0 \quad (6)$$

where $\alpha_h = -\theta_h^{-1}\left(\ln\left(\beta_h\left(1+r\right)\right)\right)$. Thus, the linearised Euler equation (6) above satisfies our hypothesis that with exception of other age effects such as those related to the precautionary motive, only age effects that are associated with the varying number of children, n_{ht} in a household explain consumption smoothing. This implies that the presence of children in a household and change in their endowment is important in explaining household welfare during pre-retirement stages of the household.

IV. Data and Welfare Indicators

This study utilizes a three-period household panel data set collected in 2001, 2003, and 2005 by two research projects. The first survey was conducted in 2001 by International Food Policy Research Institute (IFPRI), and covered two thirds of Uganda including Southwest, Central, and Eastern and some areas in Northern Uganda. A stratified sampling procedure was employed based on a classification of Uganda's territory according to the agricultural potential, market access and population density. A total of 450 households in 107 communities were interviewed in the first survey. The subsequent two surveys were conducted in 2003 and 2005 as part of the Research on Poverty, Environment, and Agricultural Technologies (REPEAT) project. In these surveys, three districts that were part of the initial IFPRI study areas were dropped due to insecurity in the North and North-eastern parts of Uganda, hence 94 out of 107 communities that were covered by the IFPRI survey in 2001 were selected. Because of the change in the sampling frame in 2003, only 333 households out of the 450 households in the baseline survey of 2001 were included in the 2003 REPEAT survey. Out of the 333 households, 20 households dropped out in the 2005 survey. This study is therefore based on a balanced panel data of 304 households, after dropping 9 more households with missing values of crop production and farm size in one or two periods. In summary, the analysis is conducted on 912 observations from 26 districts of Uganda.

[3] While the present-oriented households tend to discount the future heavily with high discount rate (low discount factor), the future -oriented households discounts the future lightly with a low discount rate (high discount factor).

Measures of Household Welfare

The conventional units of adult-equivalents, based on nutritional requirements for household members of different sex and age are used to deflate household income and expenditure. Use of adult-equivalents allow for welfare comparison across households of different size and composition. Therefore, household welfare is measured as the annual consumption expenditure per adult-equivalent, and income per adult-equivalent. Income reflects the consumption opportunity gained by a household within a specified time frame. Household income in a year was computed from the summation of (i) value of home crop production net the cost of inputs, (ii) value of home produced livestock that were consumed, (iii) cash income from sale of livestock and livestock products net of livestock production costs, and (iv) cash income from seasonal and monthly off-farm activities. Conversely, household total expenditure was constructed from cash expenditure for consumption and value of consumption of home produced goods. The two measures of household poverty levels were adjusted to 2005 prices.

V. Econometric Model Estimation and Specification

The main focus of this empirical paper is to measure the poverty impact of household endowment of children that are below 10 years of age on expenditure per adult-equivalent, while controlling for other factors that may influence household welfare. In order to ensure effective comparison across rural households, four different measures of children are employed in the analysis: the two unstandardized "absolute number of children" and "adult-equivalent of children", and two other standardized "number of children per adult-equivalent" and "the proportion (%) of children in adult-equivalents". Consistent with equation (6), the underlying unobserved effects model is given as:

$$\ln y_{ht} = \beta_0 + \beta_1 \ln N_{ht} + \beta_2 \ln \hat{H}_{ht} + \beta_3 S_{ht} + \beta_4 \ln H\hat{S}_{ht} + \beta_5 D_t + \varsigma_h + v_{ht} \qquad (7)$$

where $\ln y_{ht}$ is the log of household expenditure per adult-equivalent, $\ln N_{ht}$ is the log of each variable for the endowment of children below 10 years of age, and other exogenous variable (X_{ht}) are defined as: $\ln \hat{H}_{ht}$ the log of household human capital per adult-equivalent, S_{ht} a dummy variable for sex of household head, $\ln H\hat{S}_{ht}$ the log of the predicted household size in adult-equivalent for members that are ten years old and above, D_t represents year effects in the form of dummy variables for time periods, ς_h denotes welfare effect of the time-constant unobserved heterogeneity and, v_{ht} the time-varying unobservable variables.

The linear functional form specification $E\left(\ln y_{ht} \middle| \ln N_{ht}, \ln X_{ht}, D_t, \varsigma_h\right)$ in equation (7) is adopted after different diagnostic test results in the form of nonparametric regression between expenditure and each of the children variables (See Appendix A3, Figure A3.7, p.237, and Figure A3.9, p.238.) confirmed this relationship to be linear. The dependent and all the time-varying independent variables in equation (7) were also log transformed to ensure a symmetric distribution that has a stable variance.

Children variables are expected to be endogenous. Endogeneity bias can be attributed to measurement errors of children variables, simultaneity between household welfare and the endowment of children, and the presence of omitted variables that cannot be observed in the data (Wooldridge 2002). A test for whether children variables are endogenous or otherwise was conducted and endogeneity was confirmed using a two step Robustfied Durbin-Wu Hausman test. Using pooled OLS (see results in Table A3.4, Appendix A3 p.233) each of the actual and standardized children variables was regressed on relevant exogenous variables to generate the predicted residuals. The predicted residuals were then included in the second-step OLS regression of household expenditure on the endowment of children. Results (See Table A3.3, in Appendix A3, p.232) show that the coefficients on the "residual variable" are statistically significant at 5% level in all the four model specifications. This provides sufficient statistical evidence to strongly reject the null hypothesis that each of the children variables is exogenous.

Undoubtedly, the endowment of children is correlated with the error term in the poverty impact equation, and this violates the fundamental assumption for the consistency of ordinary least squares (OLS) estimators, and may not disappear asymptotically (Angrist & Pischke 2009; Cameron & Trivedi 2009). The lack of strong instrument to predict the children variable also did not allow the application of the ideal instrument variable (IV) approach. This study therefore employs the first-difference (FD) estimation method as the preferred approach to estimate equation (7) and the residual component (RC) approach as the robustness check.

The First Difference (FD) Method

Use of the first-difference (FD) estimator on observational panel data is effective in controlling for potential biases that are created by omitted variables and reverse causality. The FD method differences out the welfare effect of the specific household unobserved heterogeneity ς_i that is central to correlations between household welfare and the endowment of children. This is done

by lagging model covariates including dummy variables in equation (7) one period and then subtracting (Wooldridge 2009) to formulate the estimating poverty impact equation (8). Pooled OLS method is then applied to generate consistent first-difference estimates.

$$\Delta \ln y_{ht} = \delta_0 + \delta_1 \Delta \ln N_{ht} + \delta_2 \Delta \ln \hat{H}_{ht} + \delta_3 \Delta S_{ht} + \delta_4 \Delta \ln H\hat{S}_{ht} + \delta_5 \Delta D_t + e_{ht} \quad t = 2..3,\ h = 1,2,..N \qquad (8)$$

where $\Delta \ln y_{ht} = \left(\ln y_{ht} - \ln y_{h,t-1}\right)$, δ_0 is the new period intercept and all the other differenced independent variables $\left(X_{ht} - X_{h,t-1}\right)$ are defined as indicated above. The FD model assumes weak exogeneity $\left(\mathrm{E}\left(\Delta e_{ht} \middle| \varsigma_i, \Delta X_{ht}\right) = 0,\ t = 2,3\right)$, but strict exogeneity can also hold, implying that the error term $\left(e_{ht} - e_{h,t-1}\right)$ is uncorrelated with each of the differenced exogenous regressor $\left(X_{ht} - X_{h,t-1}\right)$ in the past, present and future periods. The model also assumes a full rank $\left(\sum_{t=2}^{T} E\left(\Delta X_{ht}^{'} \Delta X_{ht}\right)\right) = K$, suggesting that the FD model rules out problems of both time-constant explanatory variables and perfect collinearity among the time-varying independent variables. The analysis also depends on the assumption of no serial correlation in the first-difference of idiosyncratic errors, $u_{ht} = \left(e_{ht} - e_{h,t-1}\right)$: that is, $\mathrm{E}\left(u_{ht} u_{ht}^{'} \middle| X_{ht}, D_t, \varsigma_h\right) = \sigma_u^2 I_{T-1}$, for $t = 2,3$, and that e_{ht} follows a random walk.

The FD model is the preferred estimation method because it is easy to compute and has the ability to control for the unobserved cross section heterogeneity. The FD model provides efficient estimates under the above assumptions (Wooldridge 2002), and does not require use of strong and valid instruments to control for the endogeneity bias, which is the Achilles heel of the IV approach. Step-wise regression was employed to estimate equation (8), without the adult human capital variable in the first-step, and with adult human capital variable in the second-step that is able to capture the likely trade-off between the returns to investment in human capital of children in relation to that of working age adults in a household.

Sensitivity analysis

The first-difference (FD) method can give consistent parameters in equation (7) by removing the effect of all the time-invariant observable and unobservable factors. The effect of time-varying heterogeneity may however remain, To the extent that time-varying heterogeneity is simultaneously correlated with the children variable and household expenditure, this may create

bias in the estimates. Here the effect of time-varying endogeneity is assumed to be weak and less likely to bias the FD estimates. Distinctively, the residual component (RC) approach is employed to check the robustness of the main estimates as explained in detail in Appendix A.

Angrist and Pischke (2009) argues in favour of sensitivity analysis, given its advantages in asserting robustness of the estimated results, especially when there are changes in the sample, when additional controls are added, or when the specification of the model or functional form varies. Estimates derived from the alternative robustness checks can then be thought to bound the casual effect of interest (Enyimu et al. 2006; Angrist & Pischke 2009) after factoring in the effects of the confounding omitted variables.

VI. Results and Discussion

Descriptive statistics

The descriptive statistics of variables used are provided in Table 1. The endowment of children below 10 years in a household is presented in terms of the actual number and adult-equivalent. Almost all, 298 out of 304 households had at least one child aged less than 10 years in the three periods. The number of young children reduced from 2.65 in 2001 to 2.38 in 2005, while their corresponding adult-equivalent increased from 1.50 to 1.56 in the same period. These children on average constituted 23% of the household, which is a significant proportion. The overall mean age for household head is reported to be 43.6 years compared to 37.6 years for the spouse of the household head. Notice that, the real earnings at household level increased from approx. Ug.shs 640,000 in 2001 to Ug.shs 921,000 in 2003, before reducing slightly to Ug.shs 896,000 in 2005. Similarly, household human capital as predicted from the Mincerian earning function increased from approx. Ug.shs 333,000 in 2001 to Ug.shs 486,000 in 2005, implying a steady growth rate of 9.2% per year in human capital accumulation.

In a short period, from 2001 and 2005; household size in terms of adult-equivalent decreased from 7.45 to 6.27, land operated decreased from 8.1 acres to 6.5 acres, and the proportion of households that can afford at least two meals a day increased substantially from 40% to 77%. Although, these statistics indicate an improvement in welfare, it is evident that access to land is increasingly becoming scarce. The average level of schooling is also noted to be low, but clearly on the increase. Still, there are pronounced gender differences in access to education. The years of education for the spouse increased from 5.1 in 2001 to 5.8 in 2005, while that of the household head increased from slightly 5.46 to 6.55 in the same 5 year period.

Table 1. Summary statistics of key variables in this study

	2001		2003		2005		Overall	
Variable description	N	Mean	N	Mean	N	Mean	N	Mean
Number of children below 10 years of age	298	2.65	298	2.48	298	2.38	894	2.51
		(0.11)		(0.11)		(0.11)		(0.06)
Adult equivalent of children below 10 yrs of age	298	1.50	298	1.53	298	1.56	894	1.53
		(0.06)		(0.07)		(0.07)		(0.04)
Age of household head	304	38.56	304	45.31	304	46.93	912	43.60
		(0.66)		(0.80)		(0.77)		(0.45)
Age of spouse of household head (years)	304	35.62	304	37.62	304	39.62	912	37.62
		(0.77)		(0.77)		(0.77)		(0.45)
Real annual earnings aggregated at a household level (Ug.shs)	304	640182.20	304	920523.90	304	896056.00	912	818920.70
		(55934.97)		(76996.56)		(72782.77)		(40113.45)
Log of real annual earnings aggregated at a household level	304	51.22	304	40.04	304	42.56	912	44.60
		(1.66)		(1.34)		(1.63)		(0.91)
Predicted log of real annual earnings at a household level	304	50.99	304	40.13	304	42.75	912	44.62
		(1.70)		(1.39)		(1.67)		(0.93)
Value of predicted human capital at household level (Ug.shs)	304	333300.10	304	397973.60	304	486150.40	912	405808.00
		(12041.12)		(15769.29)		(21137.40)		(9873.51)
Predicted real value of human capital per adult-equivalent/10000	304	4.47	304	6.77	304	7.93	912	6.39
(Ug.shs) derived from FE model 3 of the Mincerian earning function.		(0.09)		(0.16)		(0.19)		(0.10)
Household adult equivalent	304	7.45	304	6.02	304	6.27	912	6.58
		(0.21)		(0.19)		(0.20)		(0.12)
Land operated (acres)	304	8.10	304	5.49	304	6.49	912	6.70
		(0.51)		(0.34)		(0.40)		(0.25)
Proportion of households that affords at least 2 meals a day in the Lc1	304	0.40	304	0.77	304	0.77	912	0.65
		(0.01)		(0.01)		(0.02)		(0.01)
Education of spouse of household head (years)	224	5.10	224	5.45	224	5.81	672	5.45
		(0.19)		(0.20)		(0.18)		(0.11)
Education of household head (years)	269	5.46	269	5.93	269	6.55	807	5.98
		(0.20)		(0.21)		(0.20)		(0.12)
Household income per adult-equivalent (Ug.shs)		215867.70		340107.20		376952.7		310975.9
	304	(17511.47)	304	(29103.48)	304	(24767.04)	912	(14181.79)
Household expenditure per adult-equivalent (Ug.shs)		346208.60		379741.8		385244.3		370398.2
	304	(15208.79)	304	(38128.95)	304	(20421.81)	912	(15277.07)

Note: (i) Standard errors are in parentheses; (ii) monetary values in real terms (2005 value)

There is a striking difference between the average household real income and expenditure per adult-equivalent. While real income per adult-equivalent increased from approx. Ug.shs 216,000 in 2001 to Ug.shs 377,000 in 2005, real household expenditure per adult-equivalent also increased from Ug.shs 346,000 to Ug.shs 385,000 in the same period. Interestingly, the average real annual income of households is much lower than the corresponding real annual consumption expenditure, especially the initial year of 2001. This difference between the two measures of household welfare can possibly be attributed to consumption smoothing, but probably more important are the limitations of the data and systematic measurement errors.

There are practical difficulties in measuring income of rural households, especially those that are self-employed in agriculture. It is also possible that research instruments and field enumerators failed to identify all the hidden income especially in the initial period of 2001, where the difference between income and expenditure is more distinct. While there are problems with both measures (and a debate in the literature on which one is more appropriate to use), I have chosen to use expenditure as the more robust measure of household welfare.

Results of the First-Order Stochastic Dominance Analysis

In this section, the first-order stochastic dominance analysis was employed to rank and compare the distribution of children across households that are in different quartiles of expenditure per adult-equivalent. The question is whether households with varying levels of welfare have the number of young children that are statistically different based on the cumulative density function (CDFs). The curve for the CDF of a dominated quartile is expected to be on the left of the CDF for the dominating quartile that also has a lower cumulative density.

Figure 1 (below) shows results of the first-order stochastic dominance analysis for the child endowment between the four welfare quartiles. Notice that households in the poorest quartile 1 dominate other three quartiles in terms of the number of children, and this is followed by households in quartile 2. The number of children is therefore statistically higher in the poorest 50% of households and lower in the 50% of relatively better-off households. Households in quartile 3 and 4 have the average number of children that is statistically not different from each other, given that no dominance is observed between them. Therefore, poor households in rural Uganda have more children compared to the relatively better-off households.

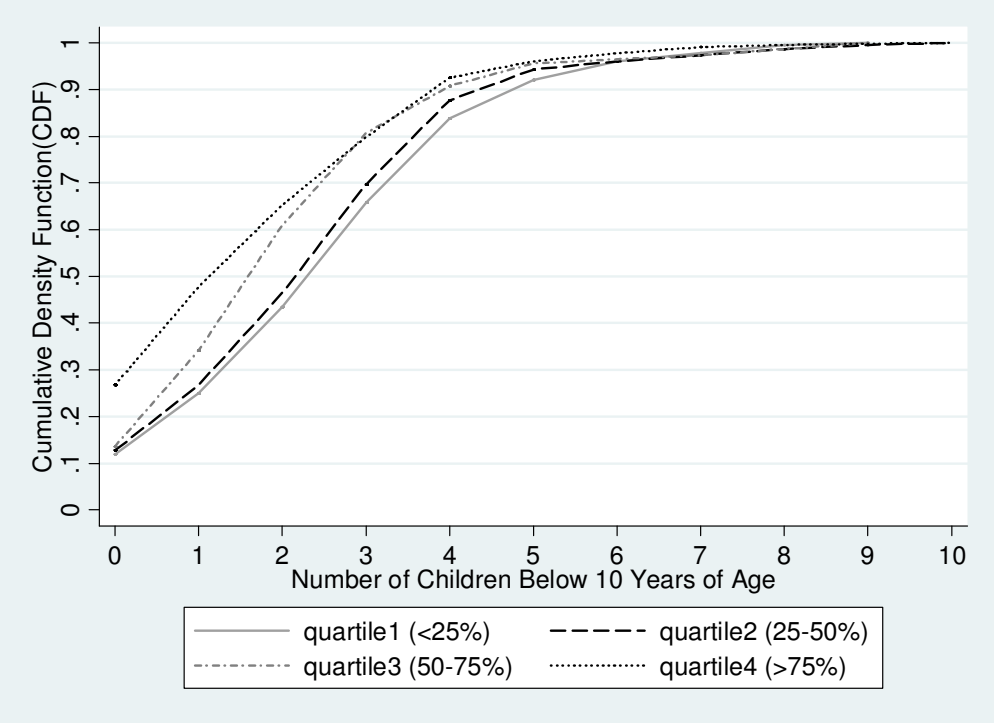

Figure 1. Households in different quartiles (25 percentiles) of expenditure per adult-equivalent and the number of young children below ten years of age

Nonparametric Results

Here I apply the nonparametric smoothing techniques to provide a simple graphical display of the interaction between the number of young children (<10 years), human capital (levels of education and health) among adult household members (>16 years), and household expenditure per adult-equivalent. This relationship can reveal the impact of the two productive assets on household welfare; that is, whether households are able to make a significant sacrifice (trade-off) by choosing to reduce (or increase) the number of children for an increase (or decrease) in the level of additional skills (human capital) of the working age adult members of the household through further investment in formal education and on-job training.

Figure 2 gives the superimposed contour and a scatter plot of the estimated joint density of the adult-equivalent of young children, and adult human capital, with a 45^0 line shown by the dotted patterns. The contour levels are increasing strictly with a shift in probability mass towards the centre. The figure shows strong negative correlation between the endowment of adult human capital and the number of young children in a household, implying that the number of children decrease with an increase in adult human capital.

Joint Distribution Contours and Netmap of Adult Human Capital and Children Endowment, without Any Conditioning

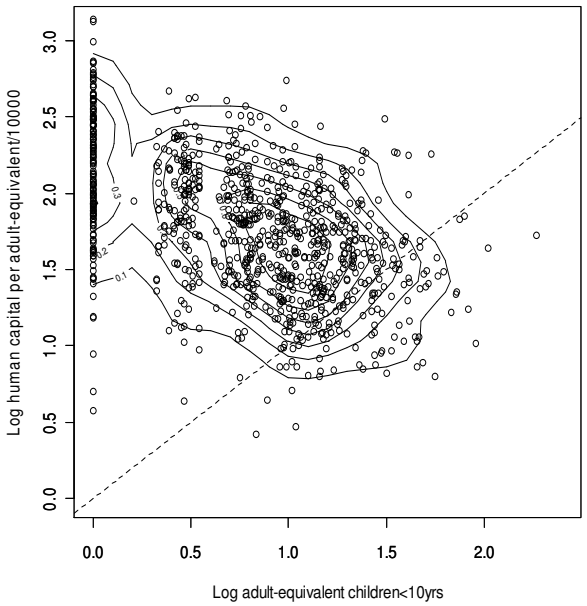

Figure 2.A contourplot of children endowment & human capital

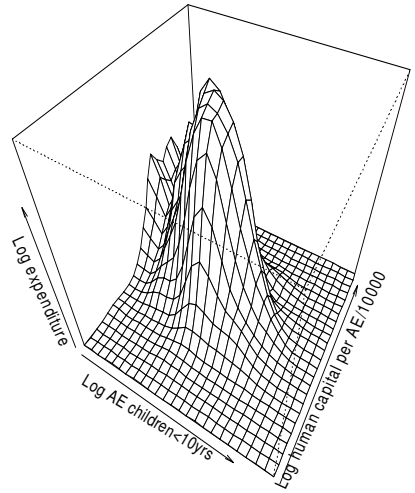

Figure 3:A netmap of children endowment & human capital

Joint Density Conditional on Median Endowment Values of other Productive Assets (size of land operated, value of owned livestock and productive farm equipments)

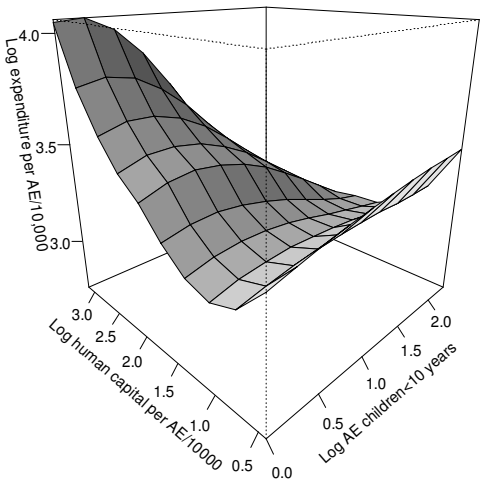

Figure 4. Surface plot of household welfare, children endowment, & human capital of adult household members

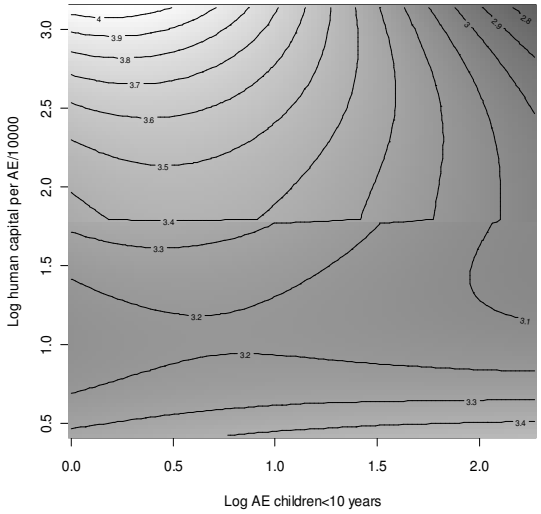

Figure 5. Contour image of children endowment & human capital of adult household members

This joint distribution is further shown in a different perspective in Figure 3, a three-dimensional density netmap or surface[41] drawing that represent a projection of household expenditure on the adult-equivalent young children, and adult human capital. According to Carter & May (2001) the greater the height of the surface plot over the plane, the greater the estimated probability that a household occupies that portion of the space. The raised probability mass is shown to occupy a portion of a plane that is more pronounced at the centre, and therefore suggests a negative correlation between the distribution of adult human capital and the adult-equivalent of children on x-axis. The welfare impact of the two endowments is more likely to be distributed close to their respective sample means.

Figures 4 and 5 employ a non-parametric smoothing technique of a locally weighted regression of the LOESS[42] function using R-software to further explore the relationship between household welfare, the endowment of children, and adult human capital. The two endowments are mapped on to household expenditure, while at the same time holding the size of land operated, the value of livestock, and value of farm equipments constant at their respective sample median values. The LOESS function assumes no functional form for the relationship between variables, and allows data to choose parameter estimates and the shape of the curve that may depend on the complex interactions of existing market imperfections (Carter & May 1999). Carter and May (1999) reports that the use of structurally similar and proximate data observations in the LOESS function can give welfare estimates that are less biased by the endogeneity of assets of interest.

Figure 4 suggest that for a given household's fixed endowment of operated land, value of livestock, and farm equipments, an increase in adult-equivalent of children appears not to generate significant welfare effect on household consumption expenditure. Initially, a small welfare effect is observed to increase slightly with an increase in adult-equivalent of children, but this quickly gets constrained, especially for households with relatively large number of children. On the other hand, one can see a sharp increase in household consumption expenditure when human capital among the adult household members increases.

[41] Deaton (1997) indicates that surface plots do not require very fine grid points, and are therefore well suited to handle the effects of distribution tails in the data.

[42] Unlike LOWESS function that employs a resistant form of smoothing; the LOESS function is sensitive to large residuals (outliers) and can also handle multidimensional smoothing (Maindonald and Braun, 2003). The method is said to be local, given that the fitted value at any point uses data within a specified neighborhood of that specific point.

The Figure 5 gives an indication on how the child endowment and adult human capital levels map into specific contours of household welfare. The contours increase towards the upper left corner of the image. Welfare level is therefore more likely to increase for households with higher levels of human capital and fewer numbers of children, holding the effect of other productive assets constant. These plots suggest that poverty level in these data is highly correlated with low levels of adult human capital and large endowments of young children.

VII. Results of the Main Estimated Econometric Model Analysis

The estimated results of the poverty impact equation based on the preferred first-differencing (FD) method are discussed in this section. The question here is whether there is a significant impact of the variation in the number and adult-equivalent of young children on household welfare. Given the nature of the first-differenced log-linear model in question, the coefficients give the approximate percentage change (elasticity) in the household expenditure per adult-equivalent, when each of the log transformed explanatory variable varies by 1 percent. Table 2 summarizes the FD model results for the actual (un-standardized) children variables (see model specifications 1-4), and the normalized (standardized) children variables to household adult-equivalent (see model specifications 5-8). The FD model estimation is conducted stepwise with, (i) only the specification of children variables and other exogenous controls in the first-step and, (ii) the inclusion of the human capital that is embodied in adult-members in the second-step to control for any potential loss of welfare (trade-offs) that may exist between household investment in the number of children as opposed to adult human capital.

As can be seen from Table 2, the coefficients on children variables are negative for the first 6 models, and are significantly different from zero in 4 of these 6 models. Conversely, model specifications 7 and 8 give positive and insignificant coefficients. Although not robust to all model specifications, this provides reasonable evidence that an increase in the endowment of children has a negative effect on the welfare of rural households, especially those with limited adult human capital endowment. The coefficient on the number of children variable in model specification 1 is -0.22 and is significantly different from zero at 1% level. This finding reflects a 22 percent relative rate of a decrease in household consumption expenditure per adult-equivalent for every one child increase in the number of children in a household. Similarly, household consumption expenditure per adult-equivalent reduces by 30.1% for every one unit increase in the adult-equivalent of children.

Further, the magnitude of the negative effect due to the increase in the endowment of children is shown to reduce by approximately 50%, when the value of human capital embodied in adult household members is controlled for in the model specifications (3, 4, 7 & 8) of the second-step. The estimated coefficients on children variables appear to lose greatly their initial level of statistical significance once the effects of adult human capital are factored into the analysis. A similar loss of the statistical significance of the welfare effects of children appears to be reinforced by the type of standardization employed, of course with the exception of model 6. Children variables are normalized to household adult-equivalent to ensure a better comparison across households with different numbers of children and different welfare levels.

It is evident that human capital variable has a strong positive impact on household consumption expenditure, and this is statistically significant at the 1% level. The models show a 35.5 - 50.7% increase in household expenditure per adult-equivalent for every proportional (one unit) increase in human capital per adult-equivalent. Noteworthy, a strong trade-off exists between investment in human capital of adult household members and that of children. The negative impact of the increase in the endowment of young children appears to reduce significantly with an increase in household human capital of the adult members. This finding is seen to be robust irrespective of whether the models in step-two are estimated with the actual or standardized variables of children. Thus, households with low investment in human capital are more likely to experience serious negative impact of having a large number of children. Such households are too constrained to make sufficient production and also face a high cost of taking care of children as consumers that clearly outweighs the returns of having children as producers The relative rate of a decrease in household welfare for every one unit increase in the endowment of children appears to reduce significantly with a proportional increase in human capital among adult-household members.

This analysis does not find therefore, strong and robust evidence in these data that children either reduce or increase household welfare in terms of consumption expenditure per adult-equivalent. This supports the recent empirical evidence that the Universal Primary Education (UPE) program may have lead to dramatic increases in primary school attendance, timely enrolment of girls and boys in rural areas, and reduced inequality in access to education (Fan & Zhang 2008; Grogan 2009). However, there can be children that may be absent from both school and economic activity due to engagement in household chores, poor health or lack of work after dropping out of school (Carter & May 2001).

Table 2. Welfare effects of the variation in the number/adult-equivalent of children below ten years of age in a household, a FD model estimation

	Differenced log of household expenditure per adult-equivalent/10,000 (Ug.shs)							
	Actual children variables				Children<10 yrs normalized to adult-equivalent			
First-differenced independent variables	1	2	3	4	5	6	7	8
Log of number of children< 10 years	-0.220***		-0.101					
	(0.06)		(0.07)					
Log of adult-equivalent children<10 years		-0.301***		-0.158*				
		(0.08)		(0.09)				
Log of number of children<10 years of age per adult-equivalent					-0.300		0.186	
					(0.19)		(0.22)	
Log proportion (% adult-equivalent) of children<10 years of age						-0.617**		0.140
						(0.28)		(0.33)
Log of human capital per adult-equivalent/10000 (Ug.shs)			0.379***	0.355***			0.507***	0.486***
			(0.11)	(0.11)			(0.11)	(0.11)
Sex of the household head (1=Male, 0=female)	0.203	0.207	0.142	0.150	0.161	0.172	0.078	0.090
	(0.18)	(0.18)	(0.17)	(0.17)	(0.18)	(0.18)	(0.17)	(0.17)
Predicted log of household size in adult-equivalent for members>=10 years	-0.340	-0.322	-0.448	-0.428	-0.422	-0.389	-0.546	-0.534
	(0.48)	(0.48)	(0.47)	(0.47)	(0.48)	(0.48)	(0.46)	(0.47)
Dummy variable for year 2003	-0.123	-0.108	-0.300**	-0.280*	-0.130	-0.109	-0.380**	-0.367**
	(0.14)	(0.14)	(0.15)	(0.15)	(0.15)	(0.15)	(0.15)	(0.15)
Dummy variable for year 2005	0.101**	0.110**	0.053	0.060	0.106**	0.110**	0.046	0.045
	(0.04)	(0.04)	(0.05)	(0.05)	(0.05)	(0.05)	(0.05)	(0.05)
Number of observations	608	608	608	608	608	608	608	608
F statistic	4.275	4.869	6.452	6.688	1.904	2.441	5.998	5.889
Prob > F	0.001	0.000	0.000	0.000	0.093	0.034	0.000	0.000
R-squared	0.038	0.044	0.062	0.065	0.016	0.021	0.060	0.058
Root MSE	0.887	0.884	0.876	0.875	0.897	0.895	0.877	0.878

Note: (i) Variables in the table are first differenced by subtracting the first lag variables, (ii) * Significant at 10%; ** significant at 5%; *** significant at 1% ,
(iii) Results in the table are in real values at 2005 prices

Further research should verify this, since the data employed in this study did not have enough information on child labor allocation in labor market, idleness, health status and disabilities. Results further show positive, but insignificant coefficients on the dummy variable for sex of the household head. This essentially means that gender difference in the welfare levels of rural Ugandan households is not substantial. While male headed households appear to enjoy relatively higher rate (7.8 - 20.7%) of increase in expenditure per adult-equivalent compared to their female headed counterparts, the difference is not statistically different from zero. The coefficients on household size measured in adult-equivalent for members that are 10 years of age and above are negative and also statistically not different from zero. The predicted household size for members of 10 years and above is introduced in the model to control for potential biases due to the endogeneity of household size, variation in the family composition, and economies of scale (Browning 1992). Though insignificant, the negative coefficients on the predicted household size reveal potential stressful conditions under which rural households operate, probably due to the prevailing market imperfections and limited economies of scale in production and consumption. The relative rate of decrease in household welfare ranges between 0.32% to 0.54% of for every 1% increase in the size of household members that are 10 and above years old.

Dummy variables for time periods were included to control for the effects of change in time relative to the excluded initial period of 2001. The coefficient on dummy variable for 2005 is positive and significant at 5% in all model specifications (models 1, 2, 5 &, 6) without human capital controls in the first-step. The coefficients indicate a significant 10.6% to 11.6% responsiveness of household expenditure per adult-equivalent that is associated with a time shift to 2005 year period from the initial year period of 2001. However, this appears to become change when human capital controls are introduced in the second-step (models 3, 4, 7, & 8) estimation. It is the coefficients on the dummy variable for 2003 that instead becomes negative and statistically different from zero, while the positive coefficients on the dummy variable for 2005 turn out to be insignificant. This switch in the sign of time effects may be associated with the trend of human capital accumulation and other factors that might have changed between 2001 and 2003.

Further sensitivity analysis

The estimated parameters are shown to be robust, whether the FD model was specified with actual children variables or normalized children variables to household adult-equivalent. In

Further sensitivity analysis of these key findings was conducted using the alternative Residual Component (RC) estimation approach is explained in detail in Appendix A. Results of the FE estimation in the first-stage are presented in Table A.2, Appendix A, and indicate the estimated coefficients that are consistent with similar signs in different model specifications of children and adult human capital variables. The model chi2-statistic values are high (251-567) and significantly different from zero at 1%, implying that the explanatory variables are able to explain reasonable variation in children and adult human capital endowment.

Results of the second-stage RC estimation of the poverty impact equation (7) are shown in Table A.1 in Appendix A. The inclusion of the predicted children and predicted adult human capital variables provides additional controls to the confounding effects of the unobserved and observed time-invariant household heterogeneity. Results show consistent parameters and were not different from results of a similar RC model without[43] the predicted additional controls of children and human capital human capital. This implies that the double FE estimation in the two stages effectively controlled for the confounding correlations of the time-invariant omitted variables.

Noteworthy, results in Tables A.1 are pretty much in line with the main FD findings. The coefficients on the residual log component children variables that are not standardized are negative and statistically different from zero at 5%. But, the statistical significance of children disappears when the second-stage model is specified with the standardized residual log component children normalized to adult-equivalent. The coefficients can be interpreted as the degree of responsiveness (elasticity) to changes in two variables. For example, the coefficients in Table A.1, the first-four model specifications indicate a 0.15% decrease in household consumption expenditure per adult-equivalent, when the number of children increases by 1% in model 1. Similarly, household expenditure decreases by 0.2% for every 1% proportional increases in the adult-equivalent of children below 10 years of age in model 2. The fact that this degree of responsiveness of household welfare to the proportional variation in the endowment of children is stable, even when human capital is controlled for, this implies that the estimated RC model parameters are consistent and robust to potential tradeoffs.

[43] Results of this alternative RC estimation not reported due to limited space in this article, but can be accessed from the author upon request.

Like in the case of the FD model estimation, the coefficients on the normalized children variables to adult-equivalent are shown to be statistically not different from zero and also have mixed signs. The findings concur with estimates of the FD model, and confirm a smaller and insignificant degree of responsiveness of household consumption expenditure per adult-equivalent to the approximate proportional increase in the endowment of children. The estimated RC parameters on other exogenous controls in the poverty impact equation are also consistent with those of the estimated FD model.

To the extent therefore that an increase in the endowment of children has a weak and insignificant effect on consumption expenditure of rural households, in a country with one of the highest fertility rates in Africa is a puzzle that needs to be examined in depth. The emerging picture from these empirical results is that large endowment of children reduces the economic returns to adult human capital and household welfare level. This appears to be the case even among households with high levels of adult human capital endowment. These findings notwithstanding, reflect progress that is being made in support of the national objective of reducing direct short-term economic benefits of children, and the promotion of long term social benefits of children through increased access to education. Further research should be done on the impact of fertility levels, child labour allocation, and incentives for school enrolment on the quality of child education in rural Uganda.

VIII. Conclusion

This study has attempted to assess the impact of the variation in the endowment of young children (<10 years) on household expenditure per adult-equivalent in rural Uganda. The article uses a unique household panel data in 2001, 2003 and 2005. Non-parametric and panel econometric methods that control for the unobserved household heterogeneity and endogeneity of young children were employed to give unbiased poverty impact estimates. The first-order stochastic dominance analysis was conducted to assess the correlation between the endowment of children and household welfare levels. Poor households dominate richer households in having a large number of young children. Household welfare was also found to increases with an increase in adult human capital and with a decrease in the number of young children, holding the effect of other productive assets constant.

The findings of the econometric regression analysis show that an increase in the number of young children generates welfare impacts that are small and largely insignificant, after

controlling for the effects of the spurious correlations of the unobserved household heterogeneity, the effects of the improvements in the health and education of adult household members, and differences in the number of children across households. A negative and significant effect of the actual number and adult-equivalent of children on the consumption expenditure per adult-equivalent was initially observed, but was later found to be clearly weak and very unstable. This implies that the short-term economic benefits parents derive from their children are limited. Children therefore have an insignificant impact on consumption level. It appears that the returns to improvements in adult human capital over the years significantly exceed the cost of having a large number of children. It is this sacrifice (trade-off) that compensates for the negative welfare effects of investing in a large number of children.

Higher investments in good education and health in rural Uganda therefore, confers a desirable shift to the number of children that are affordable and vital in strengthening household welfare in the long-term. However, this requires policy interventions that can further reduce child labour, while promoting child education and good health. These may include educational policies that reduce the marginal cost of school attendance, programs of food (and cash) transfers for school enrolment, improved technologies that can increase the productivity of adults, health policies that can reduce morbidity and mortality of children, and improvement of social security policies that can further reduce the demand for children as a form of investment.

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Appendix A

The Residual Component (RC) Estimation Method

The alternative two-stage RC method based on Holden et al. (2009) is employed as a robustness check for the main FD estimation results. The RC approach is easy to compute, gives unbiased estimates of poverty impact of the endogenous children in equation (7), and does not require strong instrument that is a challenge to the IV approach. In the first-stage, each of the endogenous log children variable $(\ln N_{ht})$ is regressed on exogenous variables (X_{ht}) and excluded instruments (Z_{ht}) using a household panel FE method to control for effects of confounding incidental parameters as specified in equation, $a1$. Similarly, the endogenous log of household human capital per adult-equivalent/10000 $\ln \hat{H}_{ht}$ is regressed on exogenous variables according to equation $a2$ in the first-stage.

$$\ln N_{ht} = \alpha_0 + \alpha_1 X_{ht} + \alpha_2 Z_{ht} + \alpha_3 D_t + c_{h1} + u_{ht} \qquad (a1)$$

$$\ln H_{ht} = \lambda_0 + \lambda_1 X_{ht} + \lambda_2 Z_{ht} + \lambda_3 D_t + c_{h2} + \varepsilon_{ht} \qquad (a2)$$

where $\ln N_{ht}$ denotes the log of children variables that include: the number of children, adult-equivalent of children, number of children per adult-equivalent, and the proportion (%) of children in terms of adult-equivalent. $\ln \hat{H}_{ht}$ represents the log of household human capital per adult-equivalent/10000, Z_{ht} represents a vector of instruments that include: age of the household head, age of the household head squared, age the household head got married, age the spouse of household head got married, the proportion of households in the smallest local government (LC1) that can afford at least two meals a day, and the dummy variable for high agricultural potential. A vector of exogenous variables X_{ht} includes sex of the household head, dummy variable for death shocks, predicted household size and dummy variables for time periods.

The error term from each of the models $a1$ and, $a2$ denote the residual log component variable for children, $(\ln \hat{N}_{ht} - \ln N_{ht})$ and the residual log component variable for human capital, $(\ln \hat{H}_{ht} - \ln H_{ht})$ that are cleaned for bias due to the unobserved heterogeneity. The FE model eliminates the unobserved time-invariant household specific effects that may be correlated with a children variable and other regressors. The FE model assumes strict exogeneity of the residual, implying that the residual log component child variable of interest is uncorrelated with other regressors. While the number of children is a limited dependent variable (LDV), human

capital is a continuous variable. The use of FE model, unlike the Tobit model in the case of children variable is based on recent evidence that nonlinear[44] models might not be different from linear models when fitting marginal effects. The impact of young children on household welfare is then estimated by including the residual component variable for children $(\ln \hat{N}_{ht} - \ln N_{ht})$ in the second-stage poverty impact equation $(a3)$ that is also estimated with household panel FE model to control for the welfare measure biases due to the unobserved household heterogeneity. The second-stage of poverty impact equation is specified as:

$$\ln y_{ht} = \zeta_0 + \zeta_1 \ln \hat{N}_{ht} + \zeta_2 (\ln \hat{N}_{ht} - \ln N_{ht}) + \zeta_3 \ln \hat{H}_{ht} + \zeta_4 (\ln \hat{H}_{ht} - \ln H_{ht}) + \zeta_5 S_{ht} + \zeta_6 \ln H\hat{S}_{ht} + \zeta_7 D_t + \varsigma_h + e_{ht} \quad t = 1, 2...3, \quad h = 1, 2, ...N \qquad (a3)$$

where $\ln \hat{N}_{ht}$ is the predicted log of children variable, $\ln \hat{H}_{ht}$ is the predicted log of human capital per adult-equivalent/10000 that are included as additional controls for unobserved household heterogeneity to enhance efficiency gains on the estimated parameters on the residual component variables. Human capital was computed using the Mincerian earning function for adult working individuals in a household according to equation a3.2, in Appendix A3 (see details, p.228-229, and results of model 3^* in Table A3.2, Appendix A3 p.231). The linear specification in equation $(a3)$ was adopted after different tests of functional form failed to identify the presence of nonlinearities. The correlation graph matrices (see Figures A3.1 to A3.6, Appendix A3, p.234-236) of variables in the first-stage and second-stage equations show random distribution of data in each cell with no peculiar patterns or extreme points.

The nonparametric regression plots in Figures A3.8, A3.10, A3.11, and A3.12 in Appendix A3, p.237-239 also suggest a linear relationship between household expenditure and different residual log component variables for children. Finally, the correlation matrix rules out the problem of colinearity between the time-varying exogenous variables in the first-stage (see Table A3.5, AppendixA3, p.240) and in second-stage (see Table A3.6, AppendixA3, p.241) estimation. The correlation coefficients between different variables including the residual log component variables are all found to be very small, in the range of 0.0165 and 0.1357. Holden et al. (2009; 2011) used the same approach to estimate investment, productivity, land rental market participation, and gender impacts of land certification in Ethiopia.

[44] Angrist and Pischke, (2009) points out that the limited dependency characteristic of a variable may not create bias in the estimates derived from a linear model.

Table A.1.Welfare effects of the variation in number or adult-equivalent of children below 10 years of age in the household, a RC estimation

	Log of household expenditure per adult-equivalent /10,000 (Ug.shs)							
	Based on FE actual children < 10 years of age				Based on FE children<10 normalized to adult-equivalent			
Independent variables	1	2	3	4	5	6	7	8
Predicted log of number of children< 10 years	-0.343***		0.792**					
	(0.09)		(0.35)					
Residual log component number of children< 10 years	-0.148**		-0.148**					
	(0.07)		(0.07)					
Predicted log adult-equivalent of children<10 years		-0.455***		1.123**				
		(0.11)		(0.51)				
Residual log component adult-equivalent of children<10 years		-0.199**		-0.199**				
		(0.09)		(0.09)				
Predicted log number of children<10 per adult-equivalent					-0.668***		1.056*	
					(0.24)		(0.60)	
Residual log component number children<10 per adult-equivalent					0.059		0.059	
					(0.25)		(0.25)	
Predicted log proportion (% adult-equivalent) of children<10						-1.083***		1.604*
						(0.35)		(0.95)
Residual log component proportion (% adult-equivalent) of children<10						-0.024		-0.024
						(0.36)		(0.36)
Predicted log human capital per adult-equivalent/10000 (Ug.shs)			1.184	1.281			0.625	0.617
			(0.82)	(0.89)			(0.75)	(0.77)
Residual log component human capital per adult-equivalent/10000 (Ug.shs)			1.107***	1.223***			0.731***	0.759***
			(0.30)	(0.37)			(0.18)	(0.20)
Sex of the household head (1=Male, 0=female)	0.295*	0.304**	-0.143	-0.189	0.256*	0.261*	0.034	0.034
	(0.15)	(0.15)	(0.22)	(0.25)	(0.15)	(0.15)	(0.18)	(0.19)
Predicted log of household size in adult-equivalent for members>=10 years	-0.245	-0.224	-0.922*	-1.002**	-0.339	-0.296	-0.646	-0.697
	(0.45)	(0.45)	(0.47)	(0.49)	(0.46)	(0.46)	(0.45)	(0.46)
Dummy variable for year 2001	0.008	-0.028	0.731	0.874	0.001	-0.038	0.424	0.475
	(0.12)	(0.12)	(0.47)	(0.54)	(0.12)	(0.13)	(0.43)	(0.47)
Dummy variable for year 2003	-0.092**	-0.107**	0.011	0.058	-0.094**	-0.105**	-0.054	-0.037
	(0.04)	(0.04)	(0.11)	(0.13)	(0.05)	(0.04)	(0.10)	(0.11)
Constant	3.819***	3.792***	1.666	1.549	3.836***	3.794***	2.723*	2.794*
	(0.65)	(0.64)	(1.70)	(1.80)	(0.65)	(0.65)	(1.61)	(1.63)
Number of observations	912	912	912	912	912	912	912	912
Number of households	304	304	304	304	304	304	304	304

	Log of household expenditure per adult-equivalent /10,000 (Ug.shs)							
	Based on FE actual children < 10 years of age				Based on FE children<10 normalized to adult-equivalent			
Independent variables	1	2	3	4	5	6	7	8
Chi2 statistic	26.021	29.035	45.432	45.720	16.900	18.300	43.623	42.654
Prob > chi2	0.000	0.000	0.000	0.000	0.010	0.006	0.000	0.000
R2-within	0.045	0.050	0.079	0.080	0.025	0.028	0.067	0.067
R2-between	0.076	0.100	0.030	0.065	0.064	0.054	0.055	0.079
R2-overall	0.059	0.072	0.035	0.066	0.041	0.040	0.055	0.071
Panel-level standard deviation (sigma_u)	0.476	0.471	0.565	0.491	0.480	0.481	0.496	0.477
Standard deviation of error term (sigma_e)	0.650	0.648	0.639	0.639	0.657	0.656	0.643	0.644
Panel fraction of variance (rho)	0.349	0.345	0.439	0.371	0.349	0.350	0.373	0.355

Note: (i) Bootstrap (399) replications) standard errors are in parentheses, (ii) * Significant at 10%; ** significant at 5%; *** significant at 1% , (iii) Results in the table are in real values at 2005 prices, (iv) human capital controls for death shock, since it excludes dead household members.

Table A.2. RC, first-stage estimation for children less than 10 years of age and human capital across rural households

	Log of children less than 10 years of age				Log of human capital per adult-equivalent
	Number	Adult-equivalent	Number per adult-equivalent	Proportion (%) in adult-Equivalent++	
Independent variables	1	2	3	4	5
Predicted log human capital per adult-equivalent/10000 (Ug.shs)	-1.041**	-1.030***	-0.455***	-0.373***	
	(0.48)	(0.39)	(0.15)	(0.10)	
Residual log component human capital per adult-equivalent/10000	-0.831***	-0.689***	-0.260***	-0.189***	
	(0.07)	(0.05)	(0.02)	(0.01)	
Sex of the household head (1 = Male, 0= female)	0.334***	0.298***	0.109***	0.080***	0.136*
	(0.11)	(0.09)	(0.03)	(0.02)	(0.08)
Dummy for deaths in a year (1 = household lost a person, 0 = otherwise)					0.165***
					(0.06)
Predicted log of household size in adult-equivalent for members>=10 years	0.382	0.332	0.045	0.061	-0.629**
	(0.32)	(0.25)	(0.09)	(0.05)	(0.26)
Dummy variable for year 2001	-0.597**	-0.662***	-0.277***	-0.256***	-0.398***
	(0.29)	(0.24)	(0.09)	(0.06)	(0.09)
Dummy variable for year 2003	-0.118	-0.158***	-0.052**	-0.057***	-0.169***
	(0.07)	(0.06)	(0.02)	(0.02)	(0.02)
Dummy for high rainfall (1= bi and uni high, 0=otherwise)	0.054	0.041	-0.023	-0.015	
	(0.06)	(0.04)	(0.02)	(0.01)	
Age of the household head (years)	-0.005	-0.005	-0.003	-0.002	-0.004
	(0.01)	(0.00)	(0.00)	(0.00)	(0.00)
Age of the household head squared (years)	-0.000**	-0.000	-0.000***	-0.000***	0.000**
	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
Age, household head got married (years)	0.006	0.006	0.003	0.003	0.001
	(0.01)	(0.01)	(0.00)	(0.00)	(0.01)
Age, household head's spouse got married (years)	-0.025	0.028	0.022	0.030	0.144**
	(0.09)	(0.07)	(0.03)	(0.02)	(0.07)
Proportion of households that can afford at least 2 meals a day	0.009	0.012	0.015	0.011	0.069
	(0.07)	(0.06)	(0.02)	(0.01)	(0.05)
Constant	2.965**	1.654	0.734	0.247	-0.173
	(1.43)	(1.12)	(0.50)	(0.35)	(1.49)
Household fixed effects estimation	Yes	Yes	Yes	Yes	Yes

	Log of children less than 10 years of age				Log of human capital per adult-equivalent
	Number	Adult-equivalent	Number per adult-equivalent	Proportion (%) in adult-Equivalent++	
Independent variables	1	2	3	4	5
Number of observations	912	912	912	912	912
Number of households	304	304	304	304	304
Chi2 statistic	250.557	263.786	481.586	567.365	439.359
Prob > chi2	0.000	0.000	0.000	0.000	0.000
R2-within	0.355	0.353	0.456	0.488	0.454
R2-between	0.259	0.372	0.441	0.302	0.005
R2-overall	0.258	0.353	0.441	0.381	0.026
Panel-level standard deviation (sigma_u)	0.473	0.278	0.106	0.082	1.059
Standard deviation of error term (sigma_e)	0.428	0.344	0.128	0.084	0.320
Rho (Panel fraction of variance)	0.549	0.395	0.405	0.488	0.916

Note: (i) Bootstrap (399) replications) standard errors are in parentheses, (ii) * Significant at 10%; ** significant at 5%; *** significant at 1%,
(iii) ++ in model 4 indicates the proportion of children below 10 years in a household measured in adult-equivalent.

Paper IV

Welfare Impacts of Access to Livestock Holdings and Endowment of Productive Farm Equipments in Rural Uganda

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ABSTRACT: *This article assesses the impact of accumulating additional productive farm equipments and more holdings of livestock in terms of real value and tropical livestock units on real household expenditure per adult-equivalent. Using a balanced panel data of 304 households surveyed in 2001, 2003 and 2005, the residual component panel econometric method and the alternative first-differencing approach were employed to estimate the poverty impact equation and to control for the endogeneity of access to productive assets and unobserved household heterogeneity. The analysis found significant welfare increasing effects of access to more livestock holdings and productive farm equipments. The low levels of productive asset endowments in rural Uganda appear to have made access to livestock and farm equipments important instruments for poverty reduction. Inequality in access to livestock and farm equipments is high and more pronounced in high market access areas in the case of livestock asset. The endowments of livestock and productive farm equipments for the rural poor in the lower quartiles expenditure per adult-equivalent distribution are statistically lower compared to endowments for households in higher quartiles of expenditure per adult-equivalent.* (JEL O12, P46 and I31)

Key words: Endogeneity of access to productive assets, unobserved heterogeneity, livestock holdings, productive farm equipments, poverty impacts.

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Welfare Impacts of Access to Livestock Holdings and Endowment of Productive Farm Equipments in Rural Uganda

I. Introduction

In Sub-Saharan Africa, productivity growth and returns to household's asset portfolios is considered to be vital for the rural poor to generate income and to secure better living standards. In this context, rural poverty can be attributed to the limited creation and facilitation of pro-poor investment options across rural households that hamper agricultural growth (Headey et al. 2010). Agricultural growth is considered to be an important instrument for poverty reduction and can be at least three times more effective in reducing poverty compared to growth from the rest of the economy (de Janvry & Sadoulet 2010). This implies that greater attention to accumulation of asset portfolios, diversification of enterprises, and further growth in agricultural yields can enhance returns to asset endowments and income for the rural poor (Riethmuller 2003; Ellis & Freeman 2004; Kristjanson et al. 2004). It is important therefore, to empirically assess the welfare effects of access and utilization of major productive assets including livestock and farm equipments that are vital in harnessing the potential of agricultural sector in Uganda.

While production and consumption of livestock and livestock products has been growing rapidly to the extent of creating a livestock revolution in Uganda and the rest of the ECA region (Delgado et al. 1999; Kristjanson et al. 2004; Pica-Ciamarra 2005; Omamo et al. 2006), a substantial proportion of rural farm households remain in poverty. The average annual growth rate in livestock products such as meats, milk, eggs, and skins in the last 7-10 years is indicated to be highest at 5.06% in Uganda, followed by 4.91% in Kenya, 4.79% in Ethiopia, and least 1.18% in Eritrea in the ECA region (Omamo et al. 2006). These high growth rates have been attributed to the increase in population, growth in GDP per capita, and urbanization that may have boosted demand for food of animal origin. These high growth rates in demand for livestock products are expected to create opportunities for the livestock sector development. The question is to what extent farm households in rural Uganda can derive significant monetary returns from their livestock endowments to increase their levels of consumption.

Livestock farmers face income uncertainty and imperfect financial markets that tend to loom large in rural areas. This creates liquidity constraints, a strong precautionary motive especially at low levels of asset endowments, and a fundamental need for affordable

insurance (Kazianga & Udry 2006). Insurance against such risk can be accomplished through building savings in asset stocks that can be liquidated in bad times to smooth[1] fluctuations in income and consumption over time (Deaton 1992b; Deaton 1992a; Sauerborn et al. 1996). Households can accumulate assets such as productive farm equipments to augment their agricultural production and to be used as collateral for credit access (Rakodi 1999; Escobal & Torero 2005). However, there is mixed empirical evidence on the poverty reduction effects of access to productive assets among the rural poor.

Recent studies in Uganda show that access to productive assets including livestock may provide rural households with a tremendous opportunity to generate income and to move out of poverty (Ellis & Bahiigwa 2003; Ellis & Freeman 2004; Lawson et al. 2006). These studies however, employed quantitative methods that may have controlled for correlations due to the unobserved household heterogeneity and endogeneity of asset endowment to a less extent. It is important therefore, to provide clear and robust estimates of the poverty reduction effects of access to livestock and farm equipments based on robust and vigorous econometric analysis that controls for the underlying spurious correlations.

This study makes a contribution to literature by providing evidence on the impact of access to productive assets on rural household welfare that is measured in terms of expenditure per adult-equivalent. Specifically, the study (i) assesses the poverty effects of the variation in access to livestock and productive farm equipments, and (ii) evaluates the level of dispersion and statistical differences in the distribution of the endowments of livestock holdings and productive farm equipments across households in different quartiles (25 percentiles) of expenditure per adult-equivalent. We expect access to productive assets to be endogenous to the household consumption decisions. This creates methodological difficulties in estimating the un-biased welfare effects of changes in these asset endowments. The analysis utilizes the residual component (RC) approach as the preferred method, and the first-differencing (FD) method as the robustness check of key results. The two methods are effective in controlling for the endogeneity of assets and correlations due to the time-invariant unobserved household heterogeneity.

[1] Poor households may choose to smooth consumption by building assets in good times and drawing them down in bad times, while others may rationally destabilize consumption to protect their productive assets from irreversible depletion (Zimmerman and Carter 2003; Lybbert and Carter, 2009).

The findings of this study indicate that low levels of productive asset endowments in rural Uganda has made access to livestock and farm equipments important instruments of poverty reduction. Inequality in access to livestock and farm equipments is also noted to be high. Also found is a clear positive correlation between household welfare and access to additional productive asset endowments. The endowments of livestock and farm equipments were found to be statistically lower for poor farm households in the lower quartiles of expenditure per adult-equivalent compared to farm households in higher quartiles of expenditure per adult-equivalent. The major finding of this study indicate significant welfare increasing effects of access to additional livestock holdings and the endowments of productive farm equipments, after controlling for the endogeneity of each of the asset endowment and the unobserved heterogeneity.

This paper is structured as follows. Section 2 reviews the status of poverty levels and policies for economic development in Uganda. In section 3, the conceptual framework that formalizes the estimating poverty impact equation is discussed. Section 4 presents the data. In section 5, the econometric estimation models of the poverty impact equation are presented. Descriptive statistics and results of the stochastic dominance analysis are summarized in section 6. In section 7 empirical findings are presented. Section 8 concludes.

II. Poverty and Policies for Economic Development in Uganda

Since 1992, Uganda has made considerable progress in poverty reduction that is attributed to the implementation of good reforms and the adoption of sound policies of investment and economic liberalization (Okidi & McKay 2003; Benin & Mugarura 2006). The share of people below poverty line declined from 56% in 1992, to 38.8% in 2003, and to 31.1% in 2006 (Appleton 2001; Okidi & McKay 2003; UBOS 2006). However, poverty levels are still high in rural areas at 34.2% compared to 13.7% in urban areas (UBOS 2006; Ministry of Finance Planning and Economic Development 2010). A substantial number of households are in transitory and persistent poverty, which presents a major challenge to sustainable economic development.

Uganda has implemented two closely linked national plans that were introduced in 1997 to reduce poverty levels and improve rural livelihoods (Ellis & Bahiigwa 2003). The Poverty Eradication Action Plan (PEAP) and the Strategic Plan for Modernization of Agriculture (PMA) are well articulated in; Bahiigwa et al., 2005; MFPED, 2000; and MAAIF and

MFPED, 2000. In particular, the PEAP has been the country's framework with the aim of reducing headcount poverty to less than 10% by 2017 by ensuring; fast and sustainable economic growth, structural transformation and macro-economic stability, good governance and security, and an increase in the ability of the poor to raise their own incomes (Ellis & Bahiigwa 2003; Ellis & Freeman 2004). The PMA also provided the country with a comprehensive and multi-sectoral plan to modernize agriculture. The two plans (PEAP and PMA) were incorporated in a five-year National Development Plan in 2010 to guide the country's development programs, and to transform Uganda from a peasant to a modern and prosperous country within the next 30 years. The aim is to boost household income, reduce poverty by turning agriculture into a profitable, competitive, sustainable, and a dynamic primary and agro-industrial enterprise, beginning with the first six operational years from 2010/11 to 2014/15.

Livestock is considered to be an important source of food, income, a store of wealth, a source of draught power, organic manure for crop production, and a means of transport especially in rural areas where the majority (85%) of Ugandans lives. Livestock production in Uganda is estimated to constitute 4.7% of GDP, and 12.6% of agricultural value added (Pica-Ciamarra 2005). About 69.4% of rural poor are engaged in livestock production. It is therefore important to boost the ability of the rural farm households to accumulate productive assets including livestock. But more importantly to enhance the productivity and returns to their asset endowments, in order to increase their income in short and medium terms.

III. Conceptual Framework

This section explains how access to productive assets may be source of risky, but high household income, based on the previous work of Rosenzweig and Wolpin (1993). Several studies have examined the ability of households to manage risk and to smooth consumption through the accumulation of buffer and productive assets in environments that are characterized by the incomplete formal financial markets, absence of insurance contracts, ubiquity of credit and liquidity constraints (Deaton & Muellbauer 1980; Deaton 1990; Deaton 1991; Deaton 1992a; Rosenzweig & Wolpin 1993; Zimmerman & Carter 2003; Kazianga & Udry 2006). The presence of borrowing constraints makes the holding of each of these assets to be non-negative. Assume also (i) that households wish to smooth their consumption, but cannot borrow for the consumption purpose, (ii) output and income are stochastic due to household level and village level shocks, and (iii) subsistence risk is a significant threat

especially for poorer households. Thus, a household h owns a fixed amount of land, A at time t that can be rented-out, divested or added to. The farmer can accumulate and employ livestock holdings, V_{ht} and productive farm equipments, M_{ht} in agricultural production or sell these to generate cash income.

The household is assumed to maximize the present value of expected lifetime utility over a finite horizon[2]. Utility at any age, t, $u\left(C_t - C_{\min}\right)$ depends on consumption of a single non-storable aggregate commodity C_t above minimum subsistence consumption, $C_{\min}$. The household therefore maximizes utility in equation (1), subject to a set of constraints, including access to and optimal use of productive asset endowments in equations (2) and (3) and initial conditions $V_{h0}, M_{h0}, \theta_{h0}^k$:

$$E_t \sum_{t=\tau}^{T} \delta^{t-\tau} u\left(C_t - C_{\min}\right) \tag{1}$$

Subject to: $$Q_{ht} = q^w\left(V_{ht}, M_{ht}, A_{ht}, X_{ht}^p, X_{ht}^h, \theta_{ht}^k\right) \tag{2}$$

$$C_{ht} \le q\left(V_{ht}, M_{ht}, \theta_{ht}^k\right) - p^v\left(V_{ht+1} - V_{ht}\right) - p^m\left(M_{ht+1} - M_{ht}\right) \tag{3}$$

where E_t is the expectation operator given the information set at time, t and, δ is the household discount factor that measures patience. The underlying risk aversion level determines the attitude of a household towards risk, and therefore creates a strong desire for the household to smooth consumption by accumulating productive assets that can generate returns for better future consumption.

Equation 2 denotes the production function that a farm household uses to generate farm income. The agricultural crop production is a two-stage process denoted as planting (p) and harvesting (h). In each period, initial decisions are made, first on how to combine productive assets with a vector of variable inputs X_t, such as seeds, fertilizers and labor. The initial cost of variable inputs X_t^p is incurred during the planting stage prior to the realization of the random production shock. The harvesting stage employs only variable inputs X_t^h that mainly include labor to reap potential yield after the resolution of uncertainty. Notice that Q_{ht}

[2] Assume that the bequest motive is not empirically important, and a general utility function. The analysis in this paper did not estimate the value of the relative risk aversion parameter.

represents agricultural output θ_{ht}^{k} represents random, idiosyncratic production shocks such as illness and livestock losses. Distinctively, equation (3) denotes the budget constraint of the household operating a specific land size, A_{ht}. The budget constraint reflects the purchasing power and possibilities of consumption and investment choices of the household (Zimmerman & Carter 2003). While, p^{v} represent price for livestock and, p^{m} denotes the price of productive farm equipments.

Let v_{t+1} denote livestock asset purchased or sold, m_{t+1} denotes purchased productive farm equipments, c^{b} is the real cost of home produced livestock, and b_{t+1} the own produced livestock asset. Each of the asset stock therefore evolves according to:

$$V_t = V_{t-1} + v_t + b_t - d_{t-1} \tag{4}$$

$$M_t = M_{t-1} + m_t^{p} - m_{t-1}^{d} \tag{5}$$

Livestock asset at, t equals the stock in previous period plus net-purchases, v_t and livestock produced at home, b_t minus livestock that died, d_{t-1}. Farm equipment stock at, t equals stock in the previous period plus net-purchases, m_t^{p} minus farm equipments divested, m_{t-1}^{d}. The new information in each period compels a household to choose new consumption and investment in productive assets based on the budget restrictions. However, the decisions to produce and consume become interrelated in presence of imperfect markets and information asymmetry. Income also becomes endogenously determined, implying that production side of farm households can be modeled to assess the effects of exogenous production shocks on consumption (Jacoby & Skoufias 1998). Household consumption is then seen as a function of profit, costs, risks and preferences.

However, the assumption of risk aversion, the complex nature of production decision, and the presence of multiple nonlinearities due to market imperfections make the solution of this optimization problem analytically intractable (Zimmerman & Carter 2003; Attanasio & Weber 2010). The problem can however be solved numerically using the ideal backward recursion of the Bellman equation, but this is beyond the scope of this paper. A (restricted) income (or profit) function (see Rosenzweig and Wolpin 1993, pg.230) conditional on asset stocks held at the beginning of the period can instead be estimated to retrieve technology parameters. Here, all the consumption smoothing above subsistence level is assumed to be

achieved based on the returns to asset endowment of livestock and productive farm equipment. Price uncertainty is also assumed to be small enough to affect price movements in villages. A (restricted) farm income function, π_{ht}^{r} can therefore take the following form:

$$\pi_{ht}^{r} = \pi_{t}\left(V_{ht}, M_{ht}, A_{ht}, \theta_{ht}^{k}\right) \tag{6}$$

The farm income for a given operated land is therefore given as:

$$\pi_{ht} = \pi_{h0} + \pi_{1}V_{ht} + \pi_{2}M_{ht} + \pi_{3}V_{ht}.M_{ht} + \pi_{4}\theta_{ht}^{k} + \pi_{5}z_{ht} \tag{7}$$

Household characteristics (Z_{ht}) can be incorporated to capture the effects of experience and gender. Equation (7) allows separate effects of different levels and interactions of each of the productive assets of interest on the profits. The intercept represents a positive farm income with zero productive assets (i.e. income from other practices). The household must sell its assets to maintain the minimum consumption level in each period, especially during periods of distress agricultural incomes. Where the full divesture of assets cannot meet the minimum consumption, household consumption must be equal to the minimum consumption plus $\psi > 0$ where ψ can be negligible. The household may have other forms of disaster insurance[3] that cushion income level from falling below the subsistence consumption. The presence of liquidity constraints also imply that household consumption must be equal to resources at hand, that is, farm income net the cost of access to assets or value of asset disposition such that:

$$\begin{aligned} C_{t} &= \pi_{t} - p^{v}v_{t+1} - p^{m}m_{t+1} - c^{b}b_{t+1} > C_{\min} + \psi \\ C_{t} &= C_{\min} + \psi;\ \text{if},\ \pi_{t} + p^{v}V_{t} + p^{m}M_{t} \le C_{\min}, \end{aligned} \tag{8}$$

The reduced poverty impact equation is therefore derived as indicated in equation (9) below:

$$C_{ht} = f\left(\pi_{t}((V_{t-1} + v_{t} + b_{t} - d_{t-1}), (M_{t-1} + m_{t}^{p} - m_{t-1}^{d})), A_{ht}, Z_{ht}, \theta_{ht}^{k})\right) > C_{\min} + \psi\,. \tag{9}$$

Consumption of a household that operates a specific land size is a function of resources at hand that can be set aside for future consumption. In other words, consumption is a function of income that is derived from household productive assets (in this case livestock and farm equipments), net costs of producing or accessing additional productive asset stock in each period as long as the minimum consumption is satisfied. After controlling for observable and unobservable factors that explain the accumulation of productive assets, households that access additional livestock and farm equipments are able to utilize their endowments more remuneratively and can enhance their welfare.

[3] For example, the household may have a fixed insurance premium paid in each period that is subtracted from π_{t} and probably contained in π_{0}.

IV. Data and Welfare Indicators

This study is based on a three-period household panel data set that was collected in 2001, 2003, and 2005 by two research projects. The first survey was conducted by the International Food Policy Research Institute (IFPRI) in 2001. It covered two thirds of Uganda including Southwest, Central, and Eastern and some areas in Northern region of the country. In this survey, a stratified sampling procedure based on the agricultural potential, market access, and population density in Uganda was employed. A total of 450 households in 107 communities were interviewed in 2001. The subsequent two surveys were conducted in 2003 and 2005 as part of the Research on Poverty, Environment, and Agricultural Technologies (REPEAT) project. In these surveys, three districts that were part of the initial IFPRI survey were dropped due to insecurity in the North and Northeastern parts of Uganda. Only 94 out of 107 communities that were covered by the IFPRI survey in 2001 were therefore selected in 2003. Furthermore, 333 households out of the 450 households in the baseline survey of 2001 were included in the 2003 REPEAT survey. Still, out of the 333 households, 20 households dropped out in the 2005 survey. This study is therefore based on a balanced panel data of 304 households, after dropping 9 more households with missing values of crop production and farm size in one or two periods. The analysis is conducted on 912 observations from 26 districts of Uganda.

Household income in a year was computed from (i) the summation of value of home crop production net of the cost of inputs, (ii) value of home produced livestock that were consumed, (iii) cash income from sale of livestock and livestock products net of livestock production costs and (iv) cash income from seasonal and monthly off-farm activities. Distinctively, household total expenditure was constructed from cash expenditure for consumption and value of consumption of home produced goods. The two measures of household poverty levels were adjusted to 2005 prices.

V. Econometric Model Specification and Estimation

The endogeneity of livestock holding and farm equipments was tested and confirmed using a manually performed robustified Wu-Hausman (DWH) test. The test employs ordinary least squares (OLS) model to fit each asset endowment on key exogenous regressors in the first-stage (see results in Appendix A4, Table A4.2, and p.243). The fitted residuals from the first-stage are then included in the outcome equation and also estimated with OLS to generate robust variance estimates that are summarized in Appendix A4, Table A4.3, p.244. The F-test

and the coefficient on the residual variable for each of the household endowment of tropical livestock units, livestock value, farm equipments and the combined value of livestock and farm equipments were found to be significant at 5-10 percent. This is a confirmation that these productive endowments are endogenous to household decisions, implying significant correlations between each of the livestock asset and farm equipments with the error term in the outcome equation.

Use of models that cannot account for the unobserved heterogeneity, sample selection and the contemporaneous correlations in the idiosyncratic errors of the outcome equation may therefore create bias in the estimated parameters (Vella & Verbeek 1999; Fernandez-Val & Vella 2007). Still, the lack of suitable instruments that are exogenous and uncorrelated with the error term in the outcome equation did not allow for the use of the ideal standard Instrument Variable (IV) approach. An alternative residual component (RC) approach was employed as the preferred econometric method to account for the unobserved time-invariant heterogeneity.

The Residual Component (RC) Approach

The Residual Component (RC) method is a two-step procedure based on (Holden et al. 2009), and gives robust estimates in absence of strong instruments. The method is easy to compute, and employs the reduced form residual component asset variable (= Asset variable - predicted asset variable) to test the impact of asset variable of interest on household expenditure per adult-equivalent. The RC method requires relevant regressors that are strictly exogenous and limited presence of the time-varying unobserved heterogeneity that may be correlated with the residual component asset variable and the outcome variable.

The endowment of livestock and farm equipments is limited dependent variable (LDV) censored at zero. And while the use of the fixed-effects (FE) model in the reduced equation for each of this LDV asset variable may generate biased estimates (Wooldridge 2005), new evidence in contemporary empirical work seems to down play the significance of this likely bias. For example, a linear model with LDV and nonlinear conditional expectation (CEF) is shown to provide remarkably robust and a best linear approximation (Angrist and Pischke, 2010) that makes functional form concerns less central.

The individual household specific effects that are time-invariant and unobservable can create endogeneity bias when they are correlated with regressors and outcomes of asset access. In order to control for this endogeneity bias, the first-stage equation (11) is estimated with the dynamic panel RE Tobit model that controls for the unobserved heterogeneity (c_{2i}) using random effects, the joint density conditional on the observed history of strictly exogenous variables, and the initial conditions (Wooldridge 2005). The model is used to generate the reduced form residuals that are seen as the residual component variable for each of the livestock and farm equipment, and also cleaned for bias due to the time-invariant unobserved heterogeneity. The first-stage dynamic panel RE Tobit model for each asset endowment is formulated as:

$$N_{ht} = \max(0, \delta X_{ht} + \varsigma D_t + c_{2h} + u^*_{2ht}) \equiv \max\left(0, N^*_{ht}\right) \tag{11}$$

where, N_{ht} denotes the endogenous asset variables for either livestock TLUs/livestock value, or value of the productive farm equipments, X_{ht} is a vector of exogenous variables including age of the household head, age of the household head squared, dummy variable for communities with high population density, dummy variable for communities with high agricultural potential, and land brought in by head and spouse at the start of the household, sex of the household head, the proportion of households that can afford at least two meals a day, the predicted household size, the unexpected shocks to the household in form of members that passed away in a year, the value of livestock lost through different means including deaths and thefts, dummy variables for time periods D_t, predicted household human capital per adult-equivalent control variable, $\hat{H}^a_{ht}$ and the residual human capital[4] component $\left(\ln H_{ht} - \ln \hat{H}_{ht}\right)$ variable that controls for the spurious correlations between human capital and unobserved household ability to access education.

Initial conditions in the form of two lagged dependent variables are also used to model the unobserved heterogeneity (c_{2i}) as indicated in below:

$$c_{2h} = \varphi + \eta N_{h0} + \lambda D_{h0} + \upsilon_h \tag{12}$$

[4] The income approach in form of the Mincerian earning function was employed to compute the household human capital stock in value terms at the individual and household level. Here, the logarithm of individual annual earnings was regressed on years of schooling and other exogenous variables predict human capital and to generate the residual human capital component variable as explained in detail in Appendix A3, p.228-231

where N_{i0} is the value of each of the livestock and farm equipments in the initial year of 2001 and, D_{i0} a dummy variable of whether a household had access to each of the two productive asset endowments in the initial year of 2001. Model (11) can therefore be reformulated to give:

$$N_{ht} = \max(0, \delta X_{ht} + \eta N_{h0} + \lambda D_{h0} + \varsigma D_t + \upsilon_h + u_{2ht}^D) \quad (13)$$

where u_{2ht}^D given the regressors $\left(u_{2ht}^D \middle| X_{ht}, N_{h0}, D_{h0}, D_t, \upsilon_h\right)$ has a normal$\left(0, \sigma_{u_2}^2\right)$ distribution, υ_h represents unobserved household heterogeneity that may persist in the model due the effects of time-varying and time-invariant factors. The model in equation (13) assumes orthogonality between c_{2h} and each of the regressors, and a much stronger exogeneity of the normally distributed idiosyncratic errors, $u_{2ht}^D = \left(N_{ht} - \hat{N}_{ht}\right) \perp c_{2h}$ that are uncorrelated with each of the regressors in each time period. Bootstrapping was used to obtain corrected standard errors, using 400 replications by re-sampling households.

The poverty impact of the variation in the endowment of livestock and farm equipments is assessed using household fixed-effects (FE) model in equation (14) to control for the welfare measure biases due to the time-constant unobserved household heterogeneity. The residual component asset variable $(N_{ht} - \hat{N}_{ht})$ is included to measure the impact of livestock and farm equipments, while the predicted asset variable per adult-equivalent $\left(\hat{N}_{ht}\right)$ is included to provide additional control for the unobserved heterogeneity. The household FE model assumes strict exogeneity of explanatory variables conditional on the unobserved effect, implying that the regresors including the residual component asset variable are uncorrelated with the idiosyncratic error that also has constant variance across, t.

$$y_{ht} = \beta_0 + \beta_1 \hat{N}_{ht} + \beta_2 (N_{ht} - \hat{N}_{ht}) + \beta_3 S_{ht} + \beta_4 T_{ht} + \beta_5 P_{ht} + \beta_6 K_{ht} + \beta_7 D_t + \varsigma_h + e_{ht} \quad (14)$$

where y_{ht} is expenditure per adult-equivalent, Z_{ht} denotes exogenous variables that include: $\left(N_{ht} - \hat{N}_{ht}\right)$ the residual asset component variable for each of livestock and farm equipments, $\hat{N}_{ht}$ representing additional controls for each of the predicted livestock and farm equipments, S_{ht} sex of the household head, T_{ht} the predicted household size[5] in terms of adult-equivalent, P_{ht} indicates the number of household members that passed away in a year, K_{ht} is the value

[5] The predicted household size in terms of adult-equivalent controls for the possible endogeneity of household size, and was predicted using panel random-effects model, see results in Table A4.1, Appendix A4. p.242

of livestock wasted through deaths, losses and thefts, D_t represents dummy variables for time periods, ς_h the welfare effect due to the unobserved and observed time-invariant household heterogeneity, and e_{ht} the error term.

Linear specification of the model variables was adopted in equation (14) after test results of diagnostic regression tests in the form of scatterplots, and nonparametric lowess and local linear fits ruled out the presence of serious nonlinearities between household expenditure and each of the livestock and farm equipments. Plots of these diagnostic regressions for the actual and residual component variables are presented in Appendix A4, Figures A4.1 to A4.8, p.245-248. Furthermore, the estimated RC parameters were bias adjusted using a bootstrapping procedure up to 400 replications to get corrected standard errors by re-sampling households. Holden et al. (2009; 2011) used the same RC approach to estimate investment, productivity land market participation, and gender impacts of land certification in Ethiopia.

Robustness Checks

The first robustness check estimated the reduced form equation for livestock holding and farm equipments using the alternative Correlated Random-Effects (CRE) Tobit model that is based on the Mundlak-Chamberlain device (Mundlak 1978; Chamberlain 1980; Chamberlain 1982; Chamberlain 1984). The CRE Tobit model controls for selection bias and unobserved household heterogeneity using random-effects, observed history of strictly exogenous variables, and the time-average conditions. The model is used to estimate equation (15) and also to generate the residual component variable of each productive asset. The Correlated Random-Effects Tobit model is specified as:

$$N_{ht} = \max(0, \delta X_{ht} + \varsigma D_t + c_{2h} + u^*_{2ht}) \equiv \max\left(0, N^*_{ht}\right) \tag{15}$$

where model variables and parameters are as explained earlier in model (11). Unobserved household heterogeneity $\left(c_{2h}\right)$ in equation (15) is controlled for by including a vector of time-average explanatory variables, $\overline{X}_i$ for each time-varying exogenous variable as shown below:

$$c_{2h} \left| X_{ht} \sim \text{Normal}\left(\varphi + \overline{X}_h \xi, \sigma_a^2\right)\right. \tag{16}$$

where $\bar{X}_{ht}$ denotes a vector of time-average, σ_a^2 is the variance of, $a_h \equiv c_{2h} - \varphi - \bar{X}_{ht}\xi$. Equation (15) can therefore be reformulated as:

$$N_{ht} = \max(0, \delta X_{ht} + \varsigma D_t + \varphi + \bar{X}_h \xi + a_i + u_{2ht}^C) \quad (17)$$

where $N_{ht} \mid X_{ht} \sim Tobit(X_{ht}\delta + D_t\varsigma + \varphi + \bar{X}_h\xi, \sigma_v^2)$, $t = 1,...,T$ and all the model variables and parameters in the Tobit model are interpreted as described earlier. The model relies on stronger assumption of exogeneity for idiosyncratic errors, $u_{2ht}^C = \left(N_{ht} - \hat{N}_{ht}\right) \perp c_{2h}$ that are normally distributed and also uncorrelated with the regressors in each time period, $u_{2ht}^C \mid (X_{ht}, D_t, c_{2h}) \approx Normal\left(0, \sigma_{u_2}^2\right)$, $t = 1,...,T$. Bootstrapping for corrected standard errors was conducted up to 400 replications by re-sampling households in different time periods.

In addition to the above RC type of robustness check, further sensitivity analysis of the main estimates to the likely effects of the time-varying omitted bias was conducted using the first-differencing (FD) method that is summarized in detail in Appendix A.

VI. Descriptive Statistics

The summary of key household characteristics, welfare indicators and the endowments of productive assets in rural Uganda are provided in Table 1. The average age of the household head is indicated to be 43.6 years, while the mean household size is reported to be 6.58 adult-equivalent persons. Land owned per adult-equivalent increased slightly from 1.05 acres in 2001 to 1.24 acres in 2005. Household human capital increased from approx. Ug.shs 45,000 per adult-equivalent in 2001 to Ug.shs 79,000 in 2005. During the same period, tropical livestock units (TLUs) per adult-equivalent reduced from 0.29 to 0.25, while livestock asset value per adult-equivalent decreased from Ug.shs 93,000 to Ug.shs 91,000. Table 1 further indicates a slight increase in the value of productive farm equipments, from the average value of Ug.shs 18,000 per adult-equivalent in 2001 to Ug.shs 19,000 in 2005.

Similarly, the mean value of household durable equipments per adult-equivalent including the productive and non-productive assets increased from Ug.shs 29,000 in 2001 to Ug.shs 60,000 in 2005. The combined value of livestock and productive equipments per adult-equivalent reduced slightly from Ug.shs 110,300 in 2001 to 109,700 in 2005. Notice that human capital loss through deaths reduced by 50% from the average of 0.88 in 2001 to 0.39 in 2005. The

value of livestock wasted through deaths, thefts and other losses reduced slightly from Ug.shs 12,100 per adult-equivalent to Ug.shs 11,900 in the same period.

TABLE 1
HOUSEHOLD CHARACTERISTICS, WELFARE INDICATORS AND ACCESS TO LAND AND NON-LAND ASSETS

	2001		**2003**		**2005**		**Overall**	
	N	Mean	N	Mean	N	Mean	N	Mean
Age of household head (yrs)	304	38.56	304	45.31	304	46.93	912	43.60
		(0.66)		(0.80)		(0.77)		(0.45)
Household adult-equivalent	304	7.45	304	6.02	304	6.27	912	6.58
		(0.21)		(0.19)		(0.20)		(0.12)
Land owned per adult-equivalent (acres)	304	1.05	304	0.97	304	1.24	912	1.09
		(0.07)		(0.08)		(0.10)		(0.05)
Human capital per adult-equivalent/10000 (Ug.shs)	304	4.47	304	6.77	304	7.93	912	6.39
		(0.09)		(0.16)		(0.19)		(0.10)
Tropical livestock units per adult-equivalent	303	0.29	303	0.22	303	0.25	909	0.25
		(0.02)		(0.02)		(0.02)		(0.01)
Livestock asset value per adult-equivalent /10000 (Ug.shs)	303	9.25	303	8.27	303	9.11	909	8.88
		(0.79)		(0.92)		(0.90)		(0.50)
Value of productive equipments/implements per adult-equivalent/10000 (Ug.shs)	304	1.80	304	1.84	304	1.89	912	1.84
		(0.13)		(0.17)		(0.17)		(0.09)
Value of durable assets per adult equivalent /10000 (Ug.shs)	304	2.93	304	4.02	304	5.96	912	4.30
		(0.55)		(0.42)		(0.94)		(0.39)
Value of livestock and productive farm equipments per adult-equivalent /10000	304	11.03	304	10.09	304	10.97	912	10.69
		(0.83)		(1.00)		(0.98)		(0.54)
Proportion of households in the LC1 that-can afford at least 2 meals a day	304	0.40	304	0.77	304	0.77	912	0.65
		(0.01)		(0.01)		(0.02)		(0.01)
Land (acres) brought in by head and spouse at the start of household	116	4.93	116	4.93	116	4.93	348	4.93
		(1.36)		(1.36)		(1.36)		(0.78)
Number of years since the household was started	304	15.51	304	17.40	304	19.38	912	17.43
		(0.69)		(0.70)		(0.70)		(0.40)
Members of the household that died/passed away in a year	98	0.88	98	0.44	98	0.39	294	0.57
		(0.10)		(0.08)		(0.06)		(0.05)
Value of livestock wasted (died/lost/stolen) per adult equivalent/10000 (Ug.shs)	221	1.21	221	0.70	221	1.19	663	1.03
		(0.13)		(0.35)		(0.27)		(0.15)
Household income per adult equivalent /10000 (Ug.shs)	304	21.59	304	34.01	304	37.70	912	31.10
		(1.75)		(2.91)		(2.48)		(1.42)
Household expenditure per adult equivalent /10000 (Ug.shs)	304	34.62	304	37.97	304	38.52	912	37.04
		(1.52)		(3.81)		(2.04)		(1.53)

NOTE: (i) Standard errors are parentheses, (ii) Asset values, income and expenditure per adult-equivalent in real values at 2005 price levels, (iii) Livestock and TLU[6] equivalent are cows = 0.5, ox = 0.5, sheep = 0.10, goats = 0.10, pigs = 0.20, donkeys = 0.5, chicken birds = 0.01, other birds (turkey, ducks and pigeons) = 0.03, and rabbits = 0.20, (iv) Productive farm equipments include: plough-sets, horse/donkey carts, wheelbarrows, boreholes, spray pumps, brewing trough, distilling equipment, fish nets, diesel pumps, water tanks, beehives, trailers, grinders, axe, pangas, slathers, hand hoes, spades, storage facilities, water tanks, bicycles, and radios.

[6] We computed Tropical Livestock Unit (TLU) equivalent for livestock species based on FAO weights for sub-Saharan Africa (See Jahnke (1982); the Compendium of Agricultural-Environmental indicators 1989-91 to 2000, Statistics Division, FAO, November, 2003).

Household real income per adult-equivalent increased from approx. Ug.shs. 216,000 in 2001 to Ug.shs 377,000 in 2005, while real expenditure per adult-equivalent increased slightly from approx. Ug.shs 346,000 to Ug.shs 385,000 in the same period. The average real annual income of households is found to be much lower than the corresponding real annual consumption expenditure. This difference is large and more distinct in the initial year of 2001. It can possibly be attributed to systematic measurement errors and data limitation. Given this anomaly, and while there problems with both measures, I have chosen to use a more reliable expenditure measure to derive the welfare effects of livestock and farm equipments.

First-Order Stochastic Dominance Analysis

The first-order stochastic dominance analysis (FOSDA) was employed assess the distribution of livestock and farm equipment across households with different levels (quartiles) of expenditure per adult-equivalent. The method uses cumulative density function (CDFs) to evaluate statistical differences in asset endowments (Levy 1992). Here, the question is whether there is a positive correlation between unique endowments of livestock and farm equipments and household welfare level. The FOSDA of dominant category of households has lower cumulative density compared to that of the dominated households, and a CDF curve that is located to the right of the CDF plot, assuming that households maximize expected utility with preference of more assets to less.

Results of the FOSDA are summarized in Appendix A, Figures 2 for the tropical livestock units per adult-equivalent and Figures 3 for the value of productive farm equipments per adult-equivalent. The CDF for TLUs among households in the lower quartile of expenditure per adult-equivalent is noted to be on the left of the alternative higher quartiles of expenditure. Livestock asset endowment is therefore, first-order stochastic dominant in the richest 25% of the households (quartile 4), followed by richer households in quartile 3, less poor households in quartile 2, and is clearly dominated among households in the poorest 25% (quartile 1). The same pattern is observed for productive farm equipments in figure 3, with households in quartile 1 and quartile 2 having almost similar low levels of productive asset endowment, compared to the level of equipments that is statistically higher for households in quartile 3, and highest for households in quartile 4.

Figure 1 (below) presents FOSDA results for the combined value of livestock and productive asset endowments. Notice that there is a first-order stochastic dominance of households in quartile 3 by households in quartile 4; households in quartile 2 by households in quartile 3 and 4; and households in quartile 1 by households in quartile 2, 3 and 4 respectively. The endowment of productive assets in form of livestock and farm equipments appear to increase with an increase in welfare levels. Compared to the richer households, the poorest households have very limited access to productive assets that may be crucial for generating autonomous incomes. This implies high levels of inequality in asset endowments as shown Table 2.

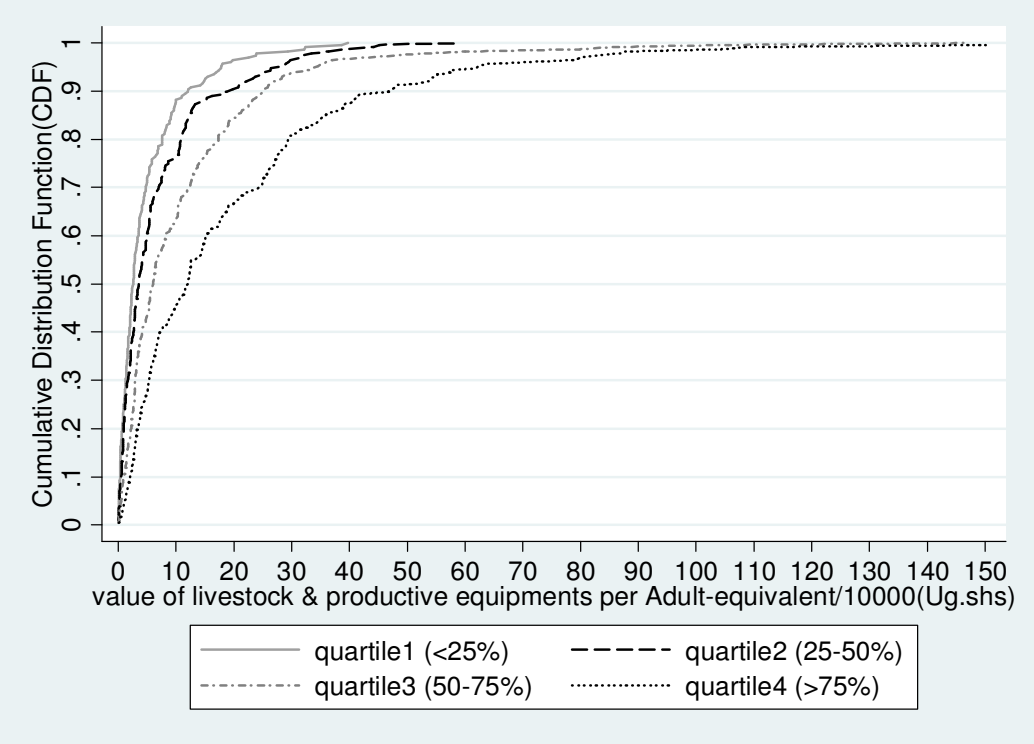

Figure1. CDF for households comparing a combined value of livestock and productive equipments (in Ug.shs) in the four welfare quartiles of expenditure per adult-equivalent, 2001-2005

The Gini coefficient is a measure of statistical dispersion that measures inequality of wealth, and is based on the characteristics of the Lorenz curve. The Gini ranges between 0 and 1, and represents the ratio of the area between the line of equality and the Lorenz curve over the total area under the line of equality. A low Gini coefficient indicates a more equal distribution, while higher Gini coefficients indicate a more unequal distribution.

TABLE2
GINI COEFFICIENTS FOR ENDOWMENTS OF LIVESTOCK AND PRODUCTIVE FARM EQUIPMENTS

Productive assets	**2001**	**2003**	**2005**	**Overall**
Tropical livestock units per adult-equivalent(TLUs)	0.6089	0.6455	0.6186	0.6258
Livestock asset value per adult-equivalent/10000 (Ug.shs)	0.6483	0.7134	0.6888	0.6841
Value of productive equipments per adult-equivalent/10000 (Ug.shs)	0.5196	0.5795	0.5733	0.5594
Value of livestock & productive equipments per adult-equivalent/10000 (Ug.shs)	0.5818	0.6487	0.6301	0.6209

Results in Table 2 show high levels of inequality in productive asset endowments in rural Uganda. And while the Gini coefficients are all above 0.5, inequality is more evident in the ownership of livestock than is the case in the endowment of productive farm equipments. This implies that most rural poor households in Uganda have limited access to productive assets compared to the relatively few rich households. The Gini-coefficient on the value of livestock holding is slightly higher than that of the tropical livestock units, probably due to the variation in the village price for livestock. Median village price was used to value household livestock endowment. Still, the higher Gini-coefficient on the value of livestock compared to TLUs may suggest the important role of market access. Households are possibly choosing to have large livestock holdings in areas with a good local price to make their investment more profitable.

VII. Results and Discussion

The welfare effects of access the productive assets were estimated using the residual component (RC) method as primary approach. Results of the first-stage estimation of the TLUs, livestock value, value of farm equipments and a combined value of livestock and farm equipments based on the dynamic panel RE Tobit model are shown in Appendix A, Table A2. The coefficients on the exogenous variables in model specifications 1-4 appear to have consistent signs and sizes. The models also have high and significant Wald chi2 statistics at 1% level, implying significant joint effect of the specified exogenous variables in the first-stage estimation.

A summary of the main estimated RC results of the second-stage poverty impact equation using household FE model are presented in Table 3. They show that access to livestock and productive farm equipments have positive coefficients on respective residual component variables that are significant at 1 percent level in model specifications 1-4.

TABLE 3
WELFARE EFFECTS OF CHANGE IN LIVESTOCK ASSET ENDOWMENT, FARM EQUIPMENTS, AND A COMBINATION OF LIVESTOCK & FARM IMPLEMENTS A RESIDUAL COMPONENT METHOD APPROACH

	Per adult-equivalent (AE) livestock asset value, and expenditure /10000 (Ug.shs)							
	Based on Dynamic RE Panel Tobit livestock				Based on Correlated RE Pooled Tobit livestock			
	TLUs	Livestock	Farm Equipment	Livestock & farm equipments	TLUs	Livestock	Farm Equipment	Livestock & farm equipments
Independent variables	1	2	3	4	5	6	7	8
Predicted tropical livestock units (TLUs) per adult-equivalent	24.444***				35.313*			
	(6.77)				(21.46)			
Residual tropical livestock units (TLUs) component per adult-equivalent	25.558***				24.265***			
	(5.73)				(4.60)			
Predicted livestock value per adult-equivalent /10000 (Ug.shs)		0.763***				1.777**		
		(0.18)				(0.77)		
Residual livestock value component per adult-equivalent/10000 (Ug.shs)		0.714***				0.688***		
		(0.13)				(0.12)		
Predicted value of farm equipments per adult-equivalent/10000 (Ug.shs)			4.659***				12.604***	
			(0.99)				(3.22)	
Residual value of farm equipments per adult-equivalent/10000 (Ug.shs)			2.708***				2.897***	
			(0.63)				(0.63)	
Predicted value of livestock & farm equipments per adult-equivalent/10,000 (Ug.shs)				1.168***				2.243***
				(0.39)				(0.82)
Residual value livestock & farm equipments component per adult-equivalent/10000 (Ug.shs)				0.537***				0.683***
				(0.17)				(0.11)
Sex of the household head (1= Male, 0=Female)	7.110	6.388	2.713	5.116	7.269	6.812	-6.892	5.397
	(5.59)	(5.16)	(5.34)	(5.29)	(5.61)	(5.49)	(6.42)	(5.44)
Predicted household size in adult-equivalent	-1.227	-0.674	-2.462	-0.083	-0.808	1.043	-2.688	1.744
	(4.65)	(4.76)	(4.64)	(5.10)	(4.79)	(4.98)	(4.89)	(5.08)
Members of the household that died/passed away in a year	-2.122	-2.549	-1.763	-3.593	-2.591	-4.397	-1.737	-5.880
	(3.34)	(3.33)	(3.54)	(3.65)	(3.46)	(3.54)	(3.47)	(3.76)
Value of livestock wasted (died/lost/stolen) per adult-equivalent/10000 (Ug.shs)	-0.844*	-1.174***	-0.750**	-1.783***	-1.047*	-2.159***	-1.010***	-2.644***
	(0.44)	(0.44)	(0.34)	(0.58)	(0.54)	(0.80)	(0.32)	(0.82)
Dummy variable for year 2001	-3.234	-2.536	3.369	-2.470	-3.814	-4.681	2.812	-4.888
	(5.08)	(5.10)	(5.39)	(5.25)	(5.63)	(5.63)	(5.23)	(5.61)

Dummy variable for year 2003	-0.279	-0.465	-1.200	-0.155	0.327	1.100	-0.976	0.951
	(4.84)	(4.79)	(4.58)	(4.89)	(5.40)	(5.42)	(4.70)	(5.12)
Constant	34.523	31.374	43.557	23.575	29.475	13.009	38.973	1.134
	(28.40)	(29.19)	(28.19)	(32.12)	(30.34)	(32.73)	(30.13)	(34.66)
Household Fixed effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Number of observations	912	912	912	912	912	912	912	912
Number of households	304	304	304	304	304	304	304	304
Chi2 statistic	35.995	42.035	43.880	55.583	35.827	43.184	55.318	57.058
Prob > chi2	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
R2-within	0.040	0.055	0.073	0.081	0.041	0.060	0.076	0.077
R2-between	0.045	0.047	0.025	0.041	0.048	0.056	0.123	0.078
R2-overall	0.042	0.052	0.052	0.064	0.044	0.058	0.093	0.075
Panel-level standard deviation (sigma_u)	28.064	28.032	28.493	28.217	28.008	27.960	26.947	27.779
Standard deviation of error term (sigma_e)	43.626	43.290	42.879	42.688	43.619	43.176	42.808	42.793
Panel fraction of variance (rho)	0.293	0.295	0.306	0.304	0.292	0.295	0.284	0.296

Note. Bootstrap (399 replications) standard errors are in parentheses. * Significant at 10%; ** significant at 5%; *** significant at 1%

In particular, the residual tropical livestock units' component per adult-equivalent in model 1 has a positive coefficient (25.558) that is significant at 1percent level. This means that households with access to 1 additional unit of TLU per adult-equivalent can increase their expenditure per adult-equivalent by Ug.shs 255,580. This translates to a gain of Ug.shs 64,662 ceteris paribus, for every 0.253 increase in the endowment of TLUs and approx. Ug.shs 127,790 for access to additional 0.5 TLUs (equivalent to a cow) per adult-equivalent. Notice, the overall average value of TLUs is indicated to be 0.253 units.

Similarly, the coefficient on the residual livestock value component per adult-equivalent in model 2 is positive (0.714) and significant at 1 percent level. With one unit of the dependent variable being equal to Ug.shs 10,000, this implies that for every Ug.shs10, 000 increase in the value of livestock per adult-equivalent, a household gains approx. Ug.shs 7,140 on expenditure per adult-equivalent. This finding is strong evidence that an increase in livestock contributes significantly to rural household welfare.

Table 3 further shows a significant (1%) and positive coefficient of 2.708 on the residual value of farm equipments per adult-equivalent in model specification 3. A household is therefore, bound to gain Ug.shs 27,080 on expenditure per adult-equivalent for every Ug.shs 10,000 increase in the value of productive farm equipments per adult-equivalent. Notice that the average value of the farm equipments per adult-equivalent is quite low at Ug.shs 18,400. The extraordinary high, but robust contribution of access to additional farm equipments on household welfare can probably be explained by the effects of; high risk, under investment in these equipments due to cash constraints, attempts to avoid the consequences of sharing (envy) in the neighborhood, and the likely time-varying endogeneity bias that could have remained in the estimated model parameters.

We also assessed the impact of the combined asset value for livestock and farm equipments in model specifications 4 in Table 3. Still, the coefficient on the residual value of livestock and farm equipment component per adult-equivalent is positive (0.527) and significant at 1% level. This shows that access to additional Ug.shs 10,000 combined value of livestock and farm equipments increases household expenditure per adult-equivalent by Ug.shs 5,370. These results confirm claims in earlier studies (Ellis & Bahiigwa 2003; Ellis & Freeman 2004; Okidi 2004; Bashaasha et al. 2006) in Uganda that access to productive assets such as livestock and durable equipments are vital to poverty reduction in rural areas. Noteworthy, the negative and

significant coefficients on the value of livestock wasted through unexpected deaths, thefts and other losses in model specifications 1-4. They imply high losses in household welfare due to the effect of devastating and unexpected shocks to the livestock endowment.

Further Robustness Checks

Recall that an alternative Correlated random-effects Tobit model that control for the time-invariant unobserved household heterogeneity using different assumptions was used to estimate the first-stage equations for household endowment of livestock and farm equipments. Results of this first-stage estimation based on the CRE Tobit are shown Appendix A, Table A3, and also have coefficients on exogenous variables that have consistent signs and sizes in 1-4 model specifications. The estimated Wald chi2 statistics are noted to be high and significant (1%), implying significant joint effect of the specified exogenous variables.

The second-stage RC results of the sensitivity analysis based on the correlated RE Tobit model in the first-stage are indicated in model specifications 5-8, Table 3. Still, the coefficients on the residual component variables for livestock and productive farm equipments are positive and significant at 1 percent level. They are not only close, but also consistent to the main RC estimates in model specifications 1-4. The residual tropical livestock units' component per adult-equivalent is shown to have a positive coefficient (24.265) that is significant at 1 percent level. This means that households with access to additional 1.0 TLU per adult-equivalent can increase their expenditure per adult-equivalent by Ug.shs 242,650. In the same line, access to additional 0.5 TLU per adult-equivalent that equivalent to one cow gives farm households approx. Ug.shs. 121,325 and this result is robust, whether the residual asset component variables are derived from the first-stage dynamic RE model (see specifications 1) or from the CRE Tobit model (specifications 5).

The coefficient on the residual livestock value component per adult-equivalent is positive (0.688) and significant at 1 percent level in model 6. This shows that every Ug.shs10, 000 increase in the value of livestock per adult-equivalent, a household gains Ug.shs 6,880 on expenditure per adult-equivalent, strong evidence that an increase in the endowment of livestock contributes significantly to rural household welfare. Similarly, the coefficient on the residual value of farm equipments per adult-equivalent in model 7 is shown to be significant (1%) and positive (2.897), and indicates that a household can gain Ug.shs 28,970 on

expenditure per adult-equivalent, when value of productive farm equipments per adult-equivalent increases by Ug.shs 10,000.

The marginal effects of the residual value of livestock and farm equipments' component per adult-equivalent in model 8 is positive (0.683) and significant at 1% level. This shows that access to additional Ug.shs 10,000 combined value of livestock and farm equipments per adult-equivalent has strong positive effect on household expenditure per adult-equivalent that is approx. Ug.shs 6,830. The estimated model specifications in the main RC method and robustness checks using a related residual component approach produced stable and consistent estimates of welfare effects of access to livestock and farm equipments. They are robust to alternative first-stage estimation of the dynamic panel RE Tobit and the correlated RE Tobit model.

Results of the RC for the outcome equation (14) are consistent with estimates of the second robustness check in the form of the FD model. The estimated results of the FD model are summarized in Appendix A, Table A1, and appear to have similar signs and magnitude of the coefficients. This indicates that these findings on the poverty reducing impact of livestock and farm equipments are valid and robust to the RC and FD estimation. In particular, results of the FD estimation show coefficients of livestock and farm equipments that are positive and significant at 1 percent level. A 1 unit increase in TLUs per adult-equivalent is shown to increase household expenditure per adult-equivalent by Ug.shs 249,440, which also translates to Ug.shs 63,108 for every 0.253 increase in TLUs per adult-equivalent. In the same line, Ug.shs 10,000 increase in value of livestock, farm equipments and combined value of livestock and farm equipments per adult-equivalent increases expenditure per adult-equivalent by Ug.shs 7,460, Ug.shs 32,010, and Ug.shs 7,570 respectively.

VIII. Conclusions

This paper has used a unique household panel data in 2001, 2003 and 2005 to assess the impact of access to additional livestock and productive farm equipments on household expenditure per adult-equivalent. Econometric methods that can control for the spurious correlations due to endogeneity of each productive asset and unobserved heterogeneity were employed. The residual component (RC) approach was used as the preferred econometric method, while the first-differencing model (FD) method was used as a robustness check. Estimates of the poverty

reducing effects of livestock and farm equipments were found to be consistent and robust to these alternative econometric methods.

The findings in this article show that the low levels of productive asset endowment in rural Uganda have made access to livestock and productive farm equipments important factors of poverty reduction. Households that can accumulate more livestock holdings and more endowment of productive farm equipments are shown to gain significant welfare improving effects. Results of the first-order stochastic dominance analysis further reveal strong positive correlation between household welfare and the endowments of livestock and farm equipments. Poor households therefore have limited access to livestock and farm equipments and their endowments are clearly dominated by those of relatively richer households. The level of inequality in the distribution of these assets is high and in the case of livestock holdings, this appears to be more pronounced in high market access areas, where the local price plays a vital role in making such investment more remunerative.

It is therefore important to adopt policy interventions that can enhance better access and accumulation of productive assets. These interventions may aim at: improving the functioning of rural factor and output markets, establishing good infrastructure, and providing affordable veterinary and extension services to minimize livestock asset losses.

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Appendix A

The First-Differencing (FD) Method

The poverty impact equation (14) was further estimated with the first-differencing (FD) transformation method as an additional robustness check. The FD model has an advantage of eliminating unobserved fixed factors that are a source of omitted variable bias and endogeneity. Household specific unobserved effect ς_h is differenced out by lagging the model one period, and then subtracting the dependent and independent variables in time-period one from time-period two, and time-period two from time-period three (Wooldridge 2009) to get:

$$\Delta y_{ht} = \delta_0 + \delta_1 \Delta N_{ht} + \delta_2 \Delta S_{ht} + \delta_3 \Delta T_{ht} + \delta_4 \Delta P_{ht} + \delta_5 \Delta K_{ht} + \delta_6 \Delta D_t + e_{ht} \qquad \text{(a1)}$$

where Δy_{ht} is differenced expenditure per adult-equivalent. The rest of the differenced exogenous variables are defined as indicated in section five of the main text. The FD estimator gives consistent parameters.

The model assumes weak exogeneity $\left[\mathrm{E}\left(\Delta e_{ht} \middle| \Delta Z_{ht}\right) = 0,\ t = 2,3\right]$ that requires the first-differenced residual e_{ht} to be uncorrelated with each of the first-differenced regressor, but can also allow the future values of the regressors to be correlated with the error term. The model also assumes a full rank that clearly rules out perfect multicolinearity among the regressors and problems of time-constant explanatory variables. It also assumes that the residual e_{ht} follows a random walk i.e. $\mathrm{E}\left(e_{ht} e_{ht}^{'} \middle| Z_{ht}, D_t, \varsigma_h\right) = \sigma_e^2 I_{T-1},\ t = 2,3$, implying that there is no serial correlation.

TABLE A1
WELFARE EFFECTS OF THE VARIATION IN TLUs, LIVESTOCK ASSET VALUE, PRODUCTIVE FARM EQUIPMENTS & A COMBINATION OF LIVESTOCK AND PRODUCTIVE FARM EQUIPMENTS, FD MODEL ESTIMATION

	First-differenced household expenditure per adult-equivalent/10000 (Ug.shs)			
	TLUs	Livestock	Farm Equipment	Livestock & farm equipments
First-differenced independent variables	1	2	3	4
Tropical livestock units (TLUs) per adult-equivalent	24.944***			
	(5.76)			
Livestock asset value per adult-equivalent /10000 (Ug.shs)		0.746***		
		(0.13)		
Value of productive farm equipments per adult-equivalent/10000 (Ug.shs)			3.201***	
			(0.87)	
Value of livestock & productive farm equipments per adult-equivalent/10,000 (Ug.shs)				0.757***
				(0.13)
Sex of the household head (1= Male, 0=Female)	6.209	5.291	1.911	4.862
	(6.34)	(5.76)	(6.27)	(5.65)
Predicted household size in adult-equivalent	-2.767	-2.681	-3.080	-2.850
	(4.78)	(4.74)	(5.07)	(4.75)
Members of the household that died/passed away in a year	0.057	-0.287	0.271	-0.302
	(3.22)	(3.13)	(3.38)	(3.11)
Value of livestock wasted (died/lost/stolen) per adult-equivalent/10000 (Ug.shs)	-0.779**	-1.119***	-0.700***	-1.224***
	(0.35)	(0.31)	(0.25)	(0.29)
Dummy variable for year 2003	0.934	-0.143	-1.380	-0.451
	(8.68)	(8.53)	(8.87)	(8.51)
Dummy variable for year 2005	0.648	1.022	1.432	1.054
	(4.69)	(4.63)	(4.67)	(4.62)
Number of observations	608	608	608	608
F statistic	3.934	6.305	4.070	7.847
Prob > F	0.000	0.000	0.000	0.000
R-squared	0.026	0.038	0.027	0.045

TABLE A2
FIRST-STAGE "RC" ESTIMATION FOR LIVESTOCK ASSET AND PRODUCTIVE FARM EQUIPMENTS, A DYNAMIC RE PANEL TOBIT MODEL

	Per adult-equivalent TLUs, & asset value /10000 (Ug.shs)			
	TLUs	Livestock	Farm Equipment	Livestock & farm equipments
	Dynamic Random Effects Panel Tobit Model			
Independent variables	1	2	3	4
Age of household head (years)	0.001	0.060	0.013	0.078
	(0.00)	(0.06)	(0.01)	(0.06)
Age of household head squared (years)	0.000	0.000	-0.000	0.000
	(0.00)	(0.00)	(0.00)	(0.00)
Dummy for high population density (1 = high, 0 = otherwise)	-0.074**	-2.202	-0.259	-2.420*
	(0.03)	(1.35)	(0.20)	(1.34)
Dummy for high agricultural potential (1= bi and uni high rainfall, 0= otherwise)	-0.049*	-1.087	-0.044	-1.028
	(0.03)	(1.17)	(0.17)	(1.16)
Land brought in by head and spouse at the start of the household (acres)	0.004	0.203*		0.131
	(0.00)	(0.11)		(0.11)
Sex of the household head (1= Male, 0=Female)	0.049	2.087	0.756***	1.643
	(0.04)	(1.55)	(0.23)	(1.39)
Predicted human capital per adult-equivalent/ 10000 (Ug.shs)	0.004	0.147	0.218***	0.426*
	(0.01)	(0.24)	(0.06)	(0.24)
Residual human capital component variable	0.009***	0.384***	0.111***	0.469***
	(0.00)	(0.12)	(0.03)	(0.12)
Proportion of households that can afford at least 2 meals a day	0.040	1.878	0.502**	1.913
	(0.04)	(1.70)	(0.24)	(1.59)
Tropical livestock units (TLUs) per adult-equivalent in the year 2001	0.939***			
	(0.03)			
Dummy variable for having TLUs per adult equivalent in the year 2001	1.896***			
	(0.22)			
Livestock value per adult-equivalent/10000 in the year 2001		0.937***		
		(0.04)		
Dummy variable for possession livestock value per adult-equivalent/10000 in the year 2001		88.026***		
		(12.11)		
Value of productive farm equipments per adult-equivalent /10000 in 2001			0.962***	
			(0.03)	
Dummy variable for possession farm equipments per adult-equivalent/10000 in 2001			15.434***	
			(2.96)	
Value of livestock & farm equipments per adult-equivalent/10000 in 2001				0.929***
				(0.04)
Dummy variable for value of livestock & farm equipments per adult-equivalent /10000 in 2001				59.139***
				(6.45)
Predicted household size in adult-equivalent	0.004	0.199	0.017	0.011
	(0.01)	(0.56)	(0.09)	(0.48)
Members of the household that died/passed away in a year	0.001	-0.089	0.016	-0.170
	(0.02)	(0.73)	(0.13)	(0.76)
Value of livestock wasted (died/lost/stolen) per adult-equivalent/10000 (Ug.shs)	0.018**	0.973*	0.118	1.066*
	(0.01)	(0.50)	(0.12)	(0.61)
Dummy variable for year 2001	-2.109***	-95.009***	-16.351***	-67.247***
	(0.23)	(12.58)	(2.87)	(6.80)
Dummy variable for year 2003	-0.030	-0.555	0.265	0.204
	(0.02)	(0.89)	(0.19)	(0.90)

Constant	0.095	-0.135	-1.411	1.386
	(0.11)	(4.34)	(0.94)	(3.93)
Panel level standard deviation (Sigma_u)	0.129***	5.877***	1.018***	5.780***
	(0.02)	(0.76)	(0.24)	(0.75)
Standard deviation of error term (Sigma_e)	0.261***	11.488***	2.086***	11.776***
	(0.03)	(1.30)	(0.28)	(1.22)
Number of observations	912	912	912	912
Number of households	304	304	304	304
Uncensored observations	814	814	874	904
Left-censored observations	98	98	38	8
Right-censored observations	0.000	0.000	0.000	0.000
Wald chi2	2258.538	1138.610	1745.804	1251.963
Prob > chi2	0.000	0.000	0.000	0.000
Rho	0.196	0.207	0.192	0.194
Log likelihood	-199.986	-3280.844	-1962.843	-3595.083

Note.(i) Bootstrap (399 replications) standard errors are in parentheses; * Significant at 10%; ** significant at 5%; *** significant at 1%.

TABLE A3
FIRST-STAGE "RC" ESTIMATION FOR LIVESTOCK ASSET AND PRODUCTIVE FARM EQUIPMENTS, A CORRELATED RE POOLED TOBIT MODEL

	Per adult-equivalent TLUs, & asset value /10000 Ug.shs)			
	TLUs	Livestock	Farm Equipment	Livestock & farm equipments
	Correlated Random Effects Pooled Tobit Model			
Independent variables	1	2	3	4
Age of household head (yrs)	-0.002	-0.110	0.062	0.008
	(0.00)	(0.12)	(0.04)	(0.12)
Age of household head squared (yrs)	0.000	0.001	-0.000	0.000
	(0.00)	(0.00)	(0.00)	(0.00)
Dummy for high population density	-0.096***	-2.983**	-0.273	-3.007**
(1 = high, 0 = otherwise)	(0.04)	(1.44)	(0.19)	(1.39)
Dummy for high agricultural potential	-0.118***	-3.020**	-0.319*	-3.038**
(1= bi and uni high rainfall, 0= otherwise)	(0.03)	(1.22)	(0.18)	(1.21)
Land brought in by head and spouse at	0.002	0.099		0.099
the start of the household (acres)	(0.00)	(0.11)		(0.09)
Sex of the household head (1= Male, 0=Female)	0.011	0.379	0.801***	0.490
	(0.06)	(2.25)	(0.24)	(2.07)
Predicted human capital per adult-equivalent/	0.004	0.282	0.327***	0.619*
10000 (Ug.shs)	(0.01)	(0.33)	(0.08)	(0.32)
Residual human capital component variable	0.016***	0.744***	0.087**	0.752***
	(0.01)	(0.21)	(0.04)	(0.20)
Proportion of households that can afford at	0.069	4.753	-0.014	4.369
least 2 meals a day	(0.09)	(4.30)	(0.61)	(4.23)
Predicted household size in adult-equivalent	-0.051	-3.297	0.261	-2.850
	(0.07)	(2.70)	(0.50)	(2.71)
Members of the household that died/passed	0.057	2.779	-0.130	2.817
away in a year	(0.06)	(2.34)	(0.33)	(2.31)
Value of livestock wasted (died/lost/stolen)	0.017**	0.921**	0.040	0.919*
per adult-equivalent/10000 (Ug.shs)	(0.01)	(0.42)	(0.13)	(0.50)
Mean age of household head (years)	0.003	0.174	-0.026	0.108
	(0.00)	(0.15)	(0.04)	(0.15)
Mean age of household head squared (years)	0.000	0.000	-0.000	0.000
	(0.00)	(0.00)	(0.00)	(0.00)
Mean predicted human capital per adult-	0.010	0.090	-0.089	0.043
equivalent/10000 (Ug.shs)	(0.01)	(0.36)	(0.07)	(0.35)
Mean residual human capital component variable	0.007	-0.024	0.167**	0.152
	(0.01)	(0.36)	(0.07)	(0.37)
Mean proportion of households that can afford	-0.059	-5.915	0.791	-5.619
at least 2 meals a day	(0.14)	(6.41)	(0.84)	(6.18)
Mean predicted household size in adult-	0.057	3.442	-0.314	2.639
equivalent	(0.07)	(2.85)	(0.53)	(2.82)
Mean number of household members that died/	-0.075	-2.594	0.339	-2.556
passed away in a year	(0.06)	(2.57)	(0.41)	(2.54)
Mean value of livestock wasted (died/lost/stolen)	0.021*	0.865*	0.250	1.108**
per adult-equivalent/10000 (Ug.shs)	(0.01)	(0.47)	(0.17)	(0.54)
Dummy variable for year 2001	0.064	3.993	0.904	5.245
	(0.10)	(4.06)	(0.91)	(4.19)
Dummy variable for year 2003	-0.054	-1.689	0.478	-0.499
	(0.04)	(1.58)	(0.33)	(1.58)

Constant	0.074	1.143	-1.900*	2.564
	(0.14)	(5.23)	(1.13)	(5.10)
sigma				
Constant	0.368***	15.006***	2.600***	14.923***
	(0.02)	(1.33)	(0.26)	(1.28)
Number of observations	912	912	912	912
Number of households				
Wald chi2	98.373	80.636	78.615	86.324
Prob > chi2	0.000	0.000	0.000	0.000
Pseudo R2	0.150	0.021	0.039	0.023
Rho				
Left-censored observations	98	98	38	8
Uncensored observations	814	814	874	904
Right-censored observations	0	0	0	0
Log likelihood	-426.382	-3442.848	-2107.708	-3733.101

Note. (i) Bootstrap (399) replications) standard errors are in parentheses. * Significant at 10%; ** significant at 5%; *** significant at 1%.

Appendix A

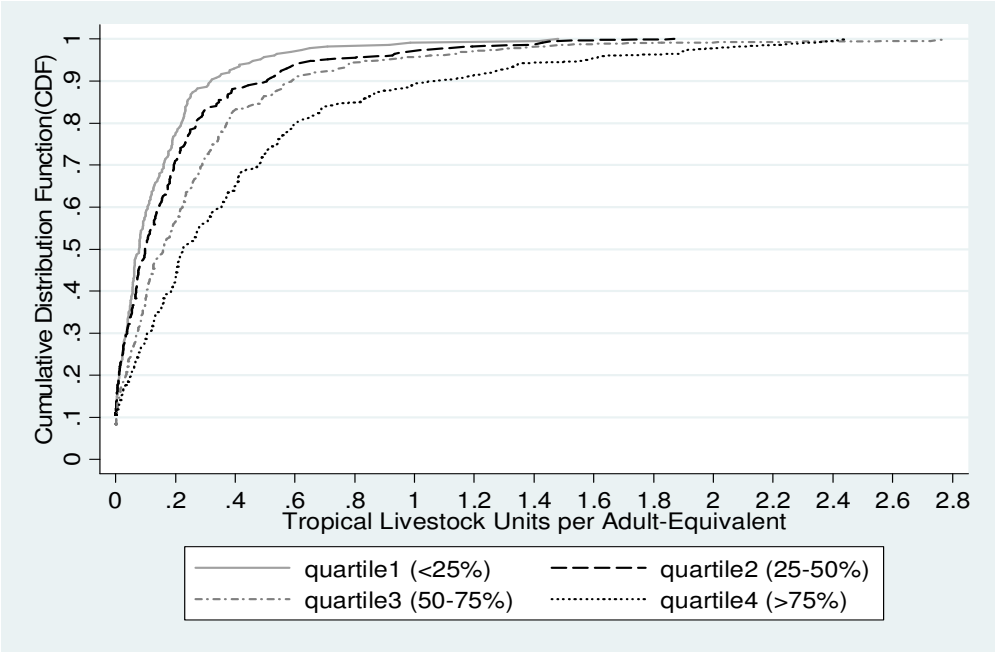

Figure 2. CDF for Rural Households in the sample comparing livestock endowment (TLUs) in the four welfare quartiles of expenditure per adult-equivalent, 2001-2005

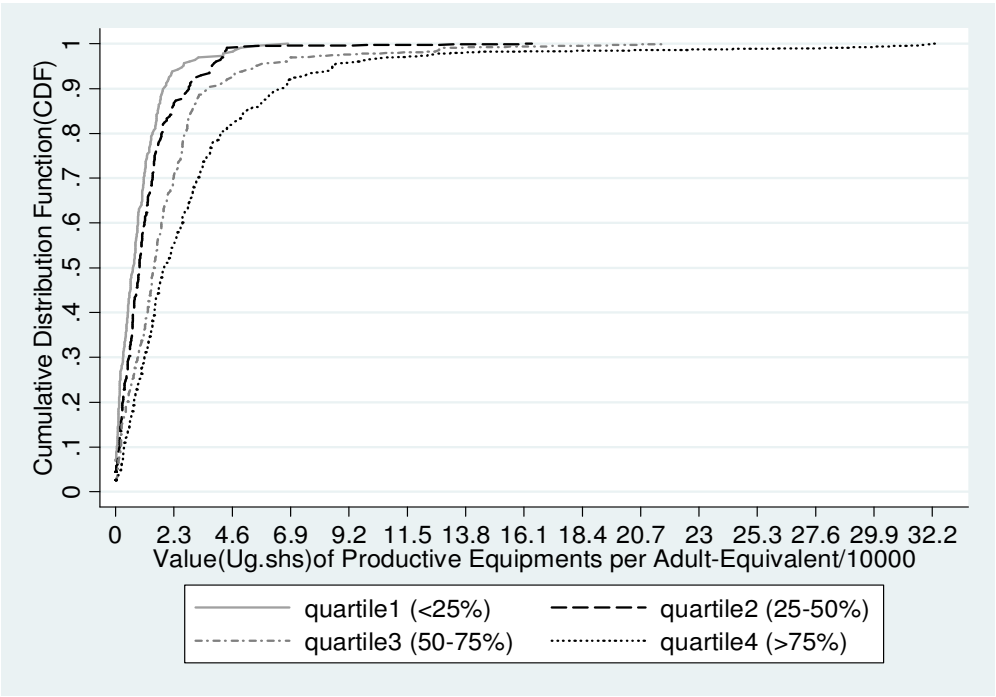

Figure 3. CDF for rural households in the sample comparing the value of productive farm equipments (in Ug.shs) in the four welfare quartiles of expenditure per adult-equivalent, 2001-2005

Paper V

Productive Asset Complementarities and Impact on Rural Poverty in Uganda

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ABSTRACT. This paper provides a synthesis of the relative poverty reduction impacts of household access to four productive assets; land operated (acres); human capital; livestock endowments; and physical farm equipments in rural Uganda. A translog production function based on first-differenced data and a semiparametric statistical smoothing method were applied to analyze a unique household panel data from 2001, 2003 and 2005, to assess the returns to each asset, and to test for asset interaction effects. Poverty was measured as consumption expenditure normalized to the poverty line while each asset endowment was normalized to sample mean endowment. Increases of all four assets had strong and significant poverty reduction effects. A 1% increase in human capital endowment increased consumption by 0.77% of poverty line expenditure while the returns to the other assets ranged from 0.22 for land to 0.27 for livestock and to 0.33 for farm equipments, however, these were not significantly different from each other. Only weak signs of significant interactions were found. Human capital and livestock, and livestock and farm equipment appeared to be potential substitutes in the household production process.

Key words: Access to productive assets, unobserved heterogeneity, poverty impacts, rural poverty

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Productive Asset Complementarities and Poverty Reduction in Rural Uganda

I. INTRODUCTION

Uganda has made great strides towards economic growth and poverty reduction since 1990s but, the share of population living in poverty is much higher in rural areas (34%) compared to in urban areas at 14% (Ministry of Finance Planning and Economic Development 2010). This synthesis paper, attempts to assess whether access to additional productive assets may guarantee economic growth, and whether there are potential cross-substitution possibilities between land and non-land productive assets that have become scarce and highly priced in rural Uganda. Arguably, households can reduce their production costs and inefficiency (Berndt & Wood 1975), if they change the composition of their output away from assets that are not highly productive.

Empirical evidence of the welfare effects of the variation of each of the; land asset, human capital, livestock asset and farm equipments is provided in separate papers of this thesis. The analysis in these papers show statistically significant poverty reduction effects of increased household endowments of each of the; owned land, operated land, market accesed land, value of human capital stock, livestock holdings, and productive farm equipments, after controlling for the unobserved household heterogeneity and endogeneity of changes in these productive assets. In this paper, the poverty impact of these assets is assessed at the same time, in one econometric analysis to provide additional evidence on their interaction effects.

The presence of unexpected shocks and a combination of market imperfections, uninsured risk, borrowing constraints, and aversion to risk may create fluctuations in household income asset positions (Rosenzweig & Wolpin 1993; Dercon 2002; Dercon 2005; Wooldridge 2005). The variations in asset portfolios in each period tend to affect not only the remunerative use of current asset endowments, but also the time needed to adjust asset endowments back to initial optimal positions. The precise relationship between growth in household income and variation in quantity and prices of different assets can be estimated from a production function. In particular, the elasticity[51] of complementarity and elasticity of substitution can be used to assess the substitutability and complementarity of assets in the production process.

[51] Kim (2000) defines the elasticity of complementarity (EC) as a primal measure of substitution that represents the effect on relative input price of a change in the relative input quantity. Conversely, the dual measure of the elasticity of substitution (ES) indicates the effect on the relative input quantity of a change in the relative input

In Uganda, few studies have examined the direct relationship between poverty reduction and household access to different productive assets. These studies reveal valuable, but fragmented information on the general determinants of changes in poverty levels, and the impact of different productive assets on income generation. Specifically, Ellis & Bahiigwa (2003) and Ellis & Freeman (2004) employed qualitative and quatitative research methods to examined feature of rural livelihood and poverty reduction. These studies report strong correlations between low household endowments of land and livestock and high levels of rural poverty in Uganda.

Deininger & Okidi (2003) provides direct empirical evidence that initial asset ownership, coffee price increase, access to basic education and health care can strengthen income growth of households that reside in areas with improved infrastructure and access to electricity. Lawson et al.(2006) show that the lack of education, land and cattle may determine rural poverty transitions and persistence in Uganda. However, the two studies employed a mixture of explanatory variables that include initial conditions, time-varying and fixed factors to explain change in poverty. It is important to note that empirical models with such specification can produce biased estimates due to potential multicolinearity. In addition, Benin & Mugarura (2006) show that increased access to farm land can reduce poverty and enhance employment opportunities across the country. The study estimates on the household endowments of education, livestock and farm equipments appear not to be robust across the country's four regions, implying empirical evidence that may not be solid. In this study, a three period panel data is used to assess the direct impact of changes in productive asset endowments on household poverty levels in the rural areas. The analysis further provides evidence on the asset interaction effects that have not been studied by previous studies. Whether access to productive assets is able to bring in the expected poverty reduction effects, given the significant challenges households face in rural Uganda is the empirical question this study aims to answer.

This paper employs a translog production function with four assets; land operated (acres); human capital in Uganda shillings (Ug.shs); livestock endowment (Ug.shs); and physical farm equipments (Ug.shs). The main aim of this study is to assess whether there are

price. The two measures are widely used in the literature to highlight the relative importance of different factors as indicated by change in the marginal product of one asset due to the increase in the quantity of the other.

significant interactions (synergies) that characterize assets as complements or just substitutes (facilitating specialization) in household income generation in rural Uganda. Specifically, the study estimates; (i) poverty reduction impacts (elasticity measures of productivity contributions) of accumulation of productive assets and (ii) asset interaction effects.

Panel data in three periods and a parametric first-differencing (FD) model, and a semi-parametric statistical smoothing method were employed to generate consistent estimates of the poverty reduction impacts of household investment in productive assets. These methods are able to control for the potential interactions in the estimates of poverty reduction effects of different assets. The findings of this study show that household access to all four assets; operated land, human capital; livestock endowments; and physical farm equipments in rural Uganda have strong and significant poverty reduction effects. A one percent increase in human capital endowment increases consumption by 0.77% of poverty line expenditure, while the returns to the other assets ranged from 0.22 for land to 0.27 for livestock and to 0.33 for farm equipments. Human capital and livestock (significant at 10 percent level in the translog model only), and livestock and farm equipment (significant at 1 percent level in the semi-parametric model only) were found to be potential substitutes in the household production process. The evidence on interaction effects was therefore not robust to alternative specifications while the effects of each asset category were robust and highly significant.

The paper is organized as follows. Economic policies in Uganda and the role of assets in boosting household welfare are described in section 2. In section 3, the conceptual framework on asset accumulation and household production process is summarized. Data and measurement of poverty are presented in section 4, while section 5 reveals the empirical estimation methods. The discussion of results is presented in section 6, and section 7 concludes. Additional information is summarized in appendix A.

II. ECONOMIC POLICIES AND THE ROLE OF PRODUCTIVE ASSETS

In Uganda, the annual GDP growth has been stable and is reported to have increased from the average of 6.9 percent in 1990s to about 8.3 percent between 2004 and 2009 (Ministry of Finance Planning and Economic Development 2009). The incidence of poverty declined from 56 percent in 1992/93 to 31 percent in 2005/2006 and is predicted to be 24.5 percent in 2010. This success notwithstanding, the share of population living in poverty is much higher in rural areas (34%) compared to in urban areas at 14% (Ministry of Finance Planning and

Economic Development 2010). It is widely agreed that access to additional productive assets can guarantee all inclusive economic growth in the form of enhanced; returns to assets, agricultural productivity, employment opportunities and insurance to unexpected shocks (Escobal & Torero 2005; Finan et al. 2005; Moser 2006). That said, the newly introduced reforms in the education sector are reported to have improved access to education in Uganda (Fan & Zhang 2008). There is now higher and timely enrolment of girls and boys in primary schools (Grogan 2009). Still, more needs to be done to improve the general quality of schooling. The new land reforms are also expected to increase land access through better functioning of land rental and purchase markets to enhance agricultural productivity, especially in areas with shortage of land due to the rapid population growth.

The National Agricultural Advisory Services (NAADS) was established in 2001, and targets the economically active but asset poor households with support in form of planting materials, livestock, farm equipments and training that are outsourced through contracts with private providers, in a decentralized service delivery (Anderson 2008). The NAADS program and the recent comprehensive National Development Plan (NDP) aim at boosting household income, access to universal education, and employment opportunities among others.(Ministry of Finance Planning and Economic Development 2010). However, the success of these programs may depend on the ability of rural households to harness the relative contributions of different assets endowments, and the underlying asset complementarity and substitutability options to augment productivity and income.

III. CONCEPTUAL FRAMEWORK OF HOUSEHOLD WELFARE LEVEL (CONSUMPTION) AND INVESTMENT IN PRODUCTIVE ASSETS

This section presents a household production function to formalise the productivity relationship between household output and access to four different productive assets. The income and resources available for rural agricultural households may depend on the production activities (Singh et al. 1986). Thus, households tend to maximize profit on the production side based on the endogenous decision price and output (Sadoulet & de Janvry 1995). They also choose to accumulate productive assets and to allocate them in the production of the output amidist the unexpected shocks and effects of market imperfections. Depending on whether asset portfolios are complementary or substitutable, household asset choices interact in different ways to influence the performance of the production technology (Athey & Stern 2003) and demand for a specific assets.

A primal transcendental logarithmic (translog) production function framework that was proposed by Christensen et al.(1973) is adopted in this study to assess the role of assets in enhancing household productivity and poverty levels. The function allows richer specifications of the relationships between household income, productive assets and their joint interactions (Dwyfor Evans et al. 2002), and does not require the assumptions of homotheticity (nonhomothetic) and separability. The translog productions function also assumes flexible elasticity of substitution between factor assets.

Consider a household $h(=1,...,N)$ in year period $t(1,..,T)$ operating under conditions of perfect competition on both product and asset markets. The household has a concave, twice differentiable translog production function that relates the flow of total quantity of household output y_{ht} and the effects of four assets $x_{iht}(i=1,...I)$ in each year. The log transformed assets include: operated land(x_A), human capital(x_H), livestock(x_V), and farm equipments(x_M). The household income from output is represented by the total household expenditure that is considered to be a reliable measure of welfare especially in developing countries.

$$y_{ht} = F(x_L, x_H, x_V, x_M) \tag{1}$$

The translog production function can be written as:

$$\ln y_{ht} = \ln a_{0ht} + \sum_{i=1}^{n} \alpha_{iht} \ln x_{iht} + \frac{1}{2}\sum_i \sum_j \gamma_{ijht} \ln x_{iht} \ln x_{jht} \quad i \neq j; i, j = 1,..., I \tag{2}$$

where y_{ht} is the log of household output, and x_i is the log of the productive assets, i: α_{iht} and γ_{ijht} are the parameters of production function to be estimated , while $\gamma_{ijht} = \gamma_{jiht}$. In addition, the effect of change in the time trend is considered to be a reliable measure of technical change (Kim 2000). The restrictive assumption of homotheticity and linear homogeneity (constant returns to scale) were not imposed, since they are not required for estimation of this production function. The marginal effects suggest a proportionate increase in output for the relative increase in factor assets.

The translog production function is flexible, well behaved and satisfies the regulatory conditions of monotonicity and convexity that are important for its economic interpretation. Its quadratic characteristics and monotonicity means that the translog production function

produces positive marginal products of inputs $\left(MP_{iht} = \partial y_{ht} / \partial x_{iht} > 0\right)$, while convexity requires it to have a negative semi-definite bordered Hessian $\left(-1\right)^n \left|\bar{H}_n > 0\right.$ (Chung 1994). Following the previous of work of Kim, 2000, Nagarajan et al., 2002, the translog production function can be shown to generate the uncompesated inverse demand functions and Hicks elasticity of complementarity. The uncompesated inverse demand functions can then be used to estimate the Antonelli elasticity of complementarity. Kim (2000) shows the details on how the uncompensated quantity and inverse output elasticities can be used to obtain the compensated quantity elasticities and the Antonelli elasticity of complementarity (AEC).

The AEC is given by:

$$\sigma_{ij}^{AEC} = \frac{\eta_{ij}}{S_j} - \sum_j S_i \eta_{ij} = \frac{D\left(y,x\right) D_{ij}\left(y,x\right)}{D_i\left(y,x\right) D_j\left(y,x\right)} = \frac{f}{S_j} \frac{\partial \ln p_i\left(y,x\right)}{\partial \ln x_j} \quad i \neq j \tag{3}$$

where η_{ij} denotes the cross price elasticities, S_i denotes the cost share of asset x_i and p_i its market price. Also, $D\left(y,x\right)$ is the input distance function that indicates the maximum amount by which assets must be deflated or inflated to reach the boundary of the feasible production set (Diewert 1982). $D_i\left(y,x\right) = \partial D\left(y,x\right) / \partial x_i$, and $D_{ij}\left(y,x\right) = \partial^2 D\left(y,x\right) / \partial x_i \, \partial x_j = D_{ji}\left(y,x\right)$. The AEC is considered to be a true dual of the Allen-Uzawa elasticity of substitution (AES) under non-constant returns to scale (Blackorby & Russell 1981; Kim 2000). It is positive for assets that are compliments and negative for assets that are substitutes.

The alternative, Hicks elasticity of complementarity (HEC) is obtained by substituting the first partial order derivative with respect to assets $\left(F_i = \partial y / \partial x_i\right)$, and the second partial order derivative with respect to assets $\left(F_{ii} = \partial y^2 / \partial x_i^2\right)$ and $\left(F_{ij} = \partial y^2 / \partial x_i \partial x_j\right)$ in the following equation:

$$\sigma_{ij}^{HEC} = F F_{ij} / F_i F_j = \frac{F\left(x\right) F_{ij}\left(x\right)}{F_i\left(x\right) F_j\left(x\right)} = \frac{F}{F_j x_j} \frac{\partial \ln p_i\left(p_y, x\right)}{\partial \ln x_j} \quad i \neq j \tag{4}$$

where p_y is the price of output. The HEC was previously considered to be dual to the Allen-Uzawa elasticity of substitution (Hicks 1970; Sato & Koizumi 1973).

It measures[52] change in the price ratio for a change in input ratio holding the quantities of other inputs constant and output price constant. The HEC also discriminates between substitutes and complements. It is positive for assets that are complements and negative for assets that are substitutes.

The elasticity of complementarity provides a greater understanding of economics of rural asset interactions to discern the dynamics of production process and poverty. Many previous studies have employed dual eslasticities of the Allen-Uzawa elasticity of substitution (AES) and the Morishima elasticity of substitition (MES) to examine the degree of substitutability between factors, when input prices change relative to one another (Allen 1938; Hicks 1964; Hicks 1970; Christensen et al. 1973; Sato & Koizumi 1973; Berndt & Wood 1975; Chung 1987; Blackorby & Russell 1989; Nagarajan et al. 2002). These dual elasticities are derived from the estimation of direct or conditional demand functions (from the dual cost or profit functions) of the assets expressed as functions of prices.

Distinctively, substitutability between assets can be assessed based on the inverse or unconditional demand functions that show the response of prices when relative quantities of assets change (Nagarajan et al. 2002). This concept of primal elasticity of complementarity provides a measure of input substitutability when there are changes in relative quantities of assets (Hicks 1970; Blackorby & Russell 1981; Kim 2000; Nagarajan et al. 2002). The Hicks elasticity of complementarity (Hicks 1970), Morishima elasticity of complementarity (Blackorby & Russell 1981), and Antonelli elasticity of complementarity (Kim 2000) have been shown to be effective dual measures of substitution. They indicate the effect on relative input price due to change in the relative quantities of assets.

IV. DATA AND KEY VARIABLES

This study utilizes a three-period household panel data set collected in 2001, 2003, and 2005 by two research projects on "Policies for Improved Land management in Uganda" by the International Food Policy Research Institute (IFPRI) in 2001, and on "Poverty, Environment and Agricultural Technologies (REPEAT) by the Foundation for Advanced Studies on

[52] According to Stern (2008), other types of primal elasticities for complementarity and substitution include: (a) Hicks (Direct) elasticity of substitution between two assets (Hicks and Allen, 1934), (b) Pingou elasticity of complementarity (Pigou, 1934) that does not discriminate between q-substitutes and q-compliments in a more than two asset case and, (c) the Morishima elasticity of complementarity that is based on distance function (Blackorby and Russell, 1981; Kim, 2000).

International Development (FASID) in the subsequent periods. The first IFPRI survey in 2001 covered two thirds of Uganda including southwest, central, and eastern and some areas in Northern Uganda. A stratified sampling procedure was employed based on a classification of Uganda's territory according to the agricultural potential, market access and population density. A total of 450 households in 107 communities were interviewed in the first survey. The REPEAT project re-surveyed the households in 2003 and 2005, but dropped 3 districts due to insecurity in the north and north-eastern parts of Uganda. The revised sampling frame in 2003 survey, therefore covered 94 communities out of 107 communities in the initial IFPRI sample, and re-sampled 333 households out of the 450 households in the baseline survey of 2001. Still, more 20 households dropped out for various reasons in the 2005 survey. About 10 households that were found to have missing and conflicting values of crop production and farm size in one or two periods were dropped in the analysis. This study is therefore based on a balanced panel data of 303 households, with 909 observations from 26 districts of Uganda.

Measures of Household Welfare

Household welfare is approximated with consumption expenditure per adult-equivalent that is also normalized to poverty line income level. The poverty line indicates household expenditure on food and nonfood requirements in Uganda. This study employs the poverty line[53] that was computed by Yamano et al. (2004) following the calorie requirement approach defined by Appleton (2001) and Ravallion & Bidani (1994). This type of normalization helps to assess the extent to which household welfare increases in percentage terms relative to the poverty line income. The use of household expenditure per adult-equivalent takes into account the fact that consumption needs evolve over time as family composition changes (Attanasio & Browning 1995). The conventional units of adult-equivalent based on nutritional requirements for household members of different sex and age are used. This ensures meaningful welfare comparison across households in a way that takes care of variation in food requirements. In particular, household welfare is measured as the

[53] Yamano et al. (2004) computed the annual food poverty line to be Ug.shs 171,360 ($90.2) per male adult, which is equivalent to Ug.shs 14,280 (US$7.52), a cost of the simplified food basket of about 39 items per month times 12 months. Food requirement was defined based on the costs of obtaining 3,000 kilo calories per day for a male adult in rural Uganda. This was based on adult-equivalents as defined in Appleton (2001) to quantify food requirements for different age-gender groups. Households whose total expenditure per adult-equivalent was just at the food poverty line were found to spend about 31.5 percent of total expenditure on non-food items, which translated to about Ug.shs 53,960 (US$28.4). The national poverty line was therefore, identified to be at Ug.shs 225,320 (US$118.6) per person per year.

annual consumption expenditure per adult-equivalent that was constructed from cash expenditure for consumption and home produced goods and adjusted to 2005 prices.

The computation of asset endowment variables was as follows. Operated land per adult-equivalent includes land in acres that is accessed by the household, through market and non-market modes and utilized for agricultural production in each year. Human capital[54] is computed as the value of the skills and education capital of the working adult members in the households that is endogenously[55] accumulated through schooling and on-job training. The lack of data on enrollment and cost of education did not allow the use of the cost approach. Instead, the income approach was used to quantify household human capital in value terms as defined in the previous studies (Mincer 1974; Psacharopoulos & Patrinos 2002; Le et al. 2003; Wößmann 2003). According to Dwyfor Evans et al. (2002), use of school enrollment to measure human capital may be unreliable, since it represents the flow of new capital instead of the actual stock of education capital.

The livestock asset endowment includes the value of small and large livestock endowment. The value of productive farm equipments includes all the implements that are used in the production process of a household (see details of these assets in Table A2).

V. ECONOMETRIC MODEL SPECIFICATION AND ESTIMATION

The endowments of land and non-land factor assets are endogenous to the household decisions. This implies that any meaningful econometric estimation of their marginal impact on productivity needs to control for the unobservable heterogeneity (Sadoulet & de Janvry 1995; Athey & Stern 2003). Given the panel data and the fact that there are considerable fixed household and village specific factors that are unobserved and therefore a potential source of bias in OLS estimates, the first-differencing (FD) estimator is adopted to generates

[54]Human capital was computed using the income approach based on the Mincerian earning function that specifies a linear relationship between the logarithm of individual annual earnings, years of schooling and access to on-job training. Details of this human capital computation using individual level data are summarized in Appendix A3 (Tables A3.1 and A3.2, p.228-231).

[55] The paradigm of endogenous growth as defined by (Lucas, 1988) indicates that productivity growth in the economy may depend on the effects of endogenous variables such as human capital and knowledge base. There are other theories of growth including the neoclassical growth model, which puts great emphasis on the importance of exogenous technical change (Solow, 1956); and also another part of the literature that emphasizes the importance of deepening financial markets including access to credit to boost growth of output per capita in any economy as explained by Calderón and Liu (2003 and Dwyfor Evans et al. (2002). These growth theories have for a long time been the basis of studying intertemporal allocation of resources and the rate of economic growth.

consistent estimates of marginal products of assets. The FD has the advantage of controlling for the differences in behaviour and heterogeneity across households.

5.1. The First-Difference (FD) Translog Method

The first-difference (FD) approach was employed to estimate the poverty impact of the investment in productive assets. The FD estimator is obtained by performing ordinary least squares (OLS) regression on the first-differenced variables (lagging model covariates including dummy variables one period and then subtracting) in the model. The FD method is able to eliminate the time-invariant unobservable factors (ς_i) that create spurious correlations between household welfare and the endowment of each of the productive asset variables. The problem of omitted variables and reverse causality can create serious biases in the estimates of marginal products and productivity elasticities (Angrist & Pischke 2010). However, the lack of valid instruments in the data to predict each of the endogenous asset endowments, did not allow use of the standard Instrumental Variable (IV) approach in this study that had four endogenous asset endowments on the right hand side. The basic econometric poverty reduction equation employed in this article is therefore, specified as:

$$\ln y_{ht} = \beta_1 \ln x_{ht} + \beta_2 D_t + \varsigma_i + e_{ht} \qquad t = 1,2..3, \quad h = 1,2,..N \tag{5}$$

The FD econometric approach is then specified as:

$$\left(\ln y_{ht} - \ln y_{ht,t-1}\right) = \alpha\left(\ln x_{ht} - \ln x_{ht,t-1}\right) + \left(e_{ht} - e_{ht,t-1}\right) \quad t = 2..3, \qquad h = 1,2,..N \tag{6}$$

Such that, the translog equation for estimation is given by:

$$\begin{aligned}
\Delta \ln y_{ht} = {} & \alpha_{0ht} + \alpha_{1ht}\Delta \ln A_{ht} + \alpha_{2ht}\Delta \ln \hat{H}_{ht} + \alpha_{3ht}\Delta \ln V_{ht} + \alpha_{4ht}\Delta \ln M_{ht} \\
& + \gamma_{12ht}\left(\Delta \ln A_{ht}.\Delta \ln \hat{H}_{ht}\right) + \gamma_{13ht}\left(\Delta \ln A_{ht}.\Delta \ln V_{ht}\right) + \gamma_{14ht}\left(\Delta \ln A_{ht}.\Delta \ln M_{ht}\right) \\
& + \gamma_{23ht}\left(\Delta \ln \hat{H}_{ht}.\Delta \ln V_{ht}\right) + \gamma_{24ht}\left(\Delta \ln \hat{H}_{ht}.\Delta \ln M_{ht}\right) \\
& + \gamma_{34ht}\left(\Delta \ln V_{ht}.\Delta \ln M_{ht}\right) \\
& + \gamma_{11ht}\left(\Delta \ln A_{ht}.\Delta \ln A_{ht}\right) + \gamma_{22ht}\left(\Delta \ln \hat{H}_{ht}.\Delta \hat{H}_{ht}\right) \\
& + \gamma_{33ht}\left(\Delta \ln V_{ht}.\Delta \ln V_{ht}\right) + \gamma_{44ht}\left(\Delta \ln M_{ht}.\Delta \ln M_{ht}\right) + \alpha_{5ht}\Delta D_t + e_{ht}
\end{aligned} \tag{7}$$

where $\Delta \ln y_{ht} = \left(\ln y_{ht} - \ln y_{h,t-1} \right)$ denotes the differenced log of household expenditure per adult-equivalent that is also normalized to the poverty line. The vector of the log of differenced time-varying independent assets is represented by, $\Delta \ln x_{ht} = \left(\ln x_{ht} - \ln x_{h,t-1} \right)$ and includes; $\Delta \ln A_{ht}$ that denote log of operated land per adult-equivalent standardized to its sample average level, $\Delta \ln \hat{H}_{ht}$ representing the log of value of household human capital per adult-equivalent standardized to its sample mean. Other independent variables include, $\Delta \ln V_{ht}$ that represent the log of value of livestock per adult-equivalent normalized to the sample average, $\Delta \ln M_{ht}$ that signify the log value of farm equipments per adult-equivalent standardized to its sample mean, and ΔD_t that indicates dummy variables for year periods, and lastly the idiosyncratic errors indicated by, e_{ht}. The impact of year periods may indicate the measure of technical and other related changes due to the variation in the external factors that change over time.

The FD model specification assumes weak exogeneity $\mathrm{E}\left(\Delta e_{ht} \middle| \varsigma_i, \Delta X_{ht} \right) = 0,\ t = 2,3$ that allows future values of regressors to be correlated with the error (Cameron & Trivedi 2009). However, strict exogeneity can also hold such that the error term, $\left(e_{ht} - e_{h,t-1} \right)$ has zero mean and is uncorrelated with each of the first-differenced exogenous regressors $\left(X_{ht} - X_{h,t-1} \right)$ in all the past, present and future periods. The FD model is also assumed to have a full rank $\left(\sum_{t=2}^{T} E\left(\Delta X_{ht}^{'} \Delta X_{ht} \right) \right) = K$ that rules out the possibility of having problems of time-constant explanatory variables and perfect multicollinearity among the time-varying independent variables. The FD analysis also relies on the assumption of no serial correlation in the first-difference of idiosyncratic errors, $u_{ht} = \left(e_{ht} - e_{h,t-1} \right)$ implying that in all time periods, $\mathrm{E}\left(u_{ht} u_{ht}^{'} \middle| X_{ht}, D_t, \varsigma_h \right) = \sigma_u^2 I_{T-1},\ t = 2,3$ and that e_{ht} follows a random walk as explained in Wooldridge, (2002). That said, the FD model is a preferred estimation method, because it is easy to compute and has the ability to control for the unobserved time constant heterogeneity. Under these assumptions, the FD model provides efficient estimates (Wooldridge, 2002), and does not require use of instruments to control the likely problem of limited endogneity due to time-invariant unobserved heterogeneity.

Angrist and Pischke (2009, p.245-246) and Angrist and Pischke (2010, p.6-7) reiterate the importance of sensitivity analysis based on plausible alternative specifications (with and without controls) and the use better research design, in order to produce stable and credible econometric estimates. Sensitivity analysis is indispensable, especially when there are changes in the sample, when additional controls are added, or when the specification of the model varies. An alternative semi-parametric model was estimated to check the robustness of the key translog FD results.

The semiparametric generalized additive model GAM model assumes that observations for the dependent and explanatory variables are independently and identically distributed (i.i.d), such that, $\mathrm{E}\left(u_{ht} \middle| X_{ht}, D_t\right) = 0,\ t = 2,3$, although some level of conditionally heteroskedastic error process of unknown form is allowed (Li & Racine 2006). The model is able to obtain consistent parametric estimates and estimators of the unknown smooth functions. The underlying smoothing technique allows the GAM model to take variable shapes depending on the data space, which can limit the bias due to endogeneity of the key explanatory variables (Carter & May 1999). However, the FD model relies on much stronger assumptions that allows control for time-invariant heterogeneity and is able to provide more reliable estimates that are less affected by these superfluous correlations. Details of the semi-parametric model specification are presented in Appendix A. The semiparametric estimation has the advantage of producing reliable estimates based on adequate smoothing statistical fit that also controls for potential non-linearities of asset variables in the same model.

VI. DESCRIPTIVE STATISTICS

This section provides descriptive statistics for key welfare and asset endowment variables by year. Table 1 shows an increase in poverty line real household expenditure per adult-equivalent units from 1.32 in 2001 to 1.45 in 2003 and to 1.47 in 2005, implying an improvement in average household expenditure from 32 percent above the poverty line to 47 percent above the poverty line from 2001 to 2003. It is widely agreed that unlike income that is considered to be very sensitive to unexpected shocks, consumption expenditure is more smoothed over time even in developing countries and is a suitable measure of welfare (Finan et al. 2005). Its use in this study to assess the productivity and poverty impacts of access to different factor assets is therefore justified.

Table 1 further displays the ratio of various household productive asset endowments per adult-equivalent to their respective sample average value (the sample mean asset units). In particular, sample mean land owned per adult-equivalent units increased from 0.94 in 2001 to 1.09 in 2005. During the same period, units of the sample mean land operated per adult-equivalent also increased from 0.96 to 1.09. These statistics appear to suggest that most rural households have small land endowments that are below the sample mean. Distinctively, the sample mean units of household human capital per adult-equivalent increased from 0.7 in 2001 to 1.24 in 2005. It appears that more rural households are increasingly making investments in additional schooling and training to boost their skills and earnings.

TABLE 1
NORMALIZED HOUSEHOLD WELFARE, ASSET ENDOWMENTS AND HEALTH SHOCK VARIABLES, 2001-2005 (N=909)

	2001		**2003**		**2005**		**Overall**	
	N	**Mean**	**N**	**Mean**	**N**	**Mean**	**N**	**Mean**
Real household expenditure (Ug.shs) per adult-	303	1.32	303	1.45	303	1.47	909	1.42
Equivalent normalized to poverty line		(0.06)		(0.15)		(0.08)		(0.06)
Normalized variables to mean value								
Owned land (acres) per adult-equivalent	303	0.94	303	0.86	303	1.09	909	0.96
		(0.06)		(0.07)		(0.09)		(0.04)
Operated land (acres) per adult-equivalent	303	0.96	303	0.88	303	1.09	909	0.97
		(0.06)		(0.07)		(0.08)		(0.04)
Predicted household human capital (Ug.shs) at	303	0.70	303	1.06	303	1.24	909	1.00
		(0.01)		(0.02)		(0.03)		(0.02)
household level per adult-equivalent								
Number of children below 10 years	297	0.90	297	0.84	297	0.81	891	0.85
		(0.04)		(0.04)		(0.04)		(0.02)
Adult-equivalent of children below 10 years	297	0.84	297	0.84	297	0.87	891	0.85
		(0.03)		(0.04)		(0.04)		(0.02)
Tropical Livestock Units (TLU) per adult-	302	1.02	302	0.77	302	0.89	906	0.89
equivalent		(0.08)		(0.07)		(0.07)		(0.04)
Real livestock asset value (Ug.shs) per adult-	302	0.94	302	0.83	302	0.91	906	0.89
Equivalent		(0.08)		(0.09)		(0.09)		(0.05)
Real value (in Ug.shs) of equipments/	303	0.93	303	0.96	303	0.99	909	0.96
Implements per adult- equivalent		(0.07)		(0.09)		(0.09)		(0.05)
Real value of livestock and farm	303	1.02	303	0.93	303	1.01	909	0.99
equipments (Ug.shs) Per adult-equivalent		(0.08)		(0.09)		(0.09)		(0.05)

Note: Standard errors are in parentheses

Noteworthy, is the fact that the sample mean units of the "number" and the "adult-equivalent" of young children below ten years is on average low at 0.85. The sample mean number of children units decreased from 0.9 in 2001 to 0.81 in 2005. On the other hand, the sample mean units of children in adult-equivalent units increased from 0.84 to 0.87 in the same period. This is expected since the nutritional requirement of children and therefore,

their adult-equivalent increases with increase in age. The samples mean livestock value decreased from 0.94 to 0.91 between the periods of 2001 to 2005. During the same time, the sample mean value of farm equipments per adult-equivalent units increased from 0.93 to 0.99 between 2001 and 2005. However, the ratio of the combined value of livestock and farm equipments per adult-equivalent to the respective sample mean remained stable at 0.99, throughout the five year period.

Notice that the sample mean for each asset endowment was computed using only the positive endowment values (ignoring zero asset observations) across households. Furthermore, a value of 1 was also added on each of the asset endowment values and log transformed to retain zero asset observations. This implies that the relative asset ratios are clearly based on the actual, but higher sample mean that constitute only households with access to these assets. However, it is possible that this normalization effect using a relatively higher sample mean (summarized in Table A1), may combine with the effect of the log transformation of these assets to shift relative endowment position of most households away from the sample mean. This can also have implications on the size of the estimated welfare effects of each asset that may be reflected by a down bias.

An overview of household characteristics, welfare levels and actual asset endowments (with and without zero observations) is indicated in Table A1, Appendix A. Summary statistics are shown for each variable in the table with and without zero observations. They include the number, proportion of zero observations and mean value for each variable. Also presented are the mean, standard deviation, and the range of each variable when zero observations are removed. The national poverty line per adult person per year that is adopted in this paper is indicated be 261717.1 (Ug.shs) at 2005 prices.

VII. RESULTS AND DISCUSSION

Table 2 shows the estimated impact of productive factor assets on rural poverty based on the first-differencing (FD) approach. Model 1 is specified with the four key productive assets as independent variables in log form. This gives the Cobb-Douglas formulation of the model. Also included are the dummy variables for year effects to quantify the impact of technical and other changes. In addition to the above mentioned regressors, six different two-way interaction terms of the main assets are added to test the possible asset complementarities in model specification 2. The final model specification 3, which is the translog model, has the

main four assets, the six different interaction terms, and three quadratic terms of the asset variables, together with dummy variables for years . Notice that the inclusion of the quadratic log variable for human capital was found to create multicollinearity that affected the statistical significance of the linear log variable of human capital (from 1 percent to 10 percent). It was therefore, dropped from the model to ensure a robust estimated parameter on human capital. Given the log transformation on the dependent and explanatory variables, the estimated coefficients can be interpreted in terms of elasticity that approximates the Hicks elasticity of complementarity and the Antonelli elasticity of complementarity. The estimated elasticity indicates the proportional change in a response variable for every 1 unit change in the endowment of each of the assets.

Several diagnostic tests were conducted to ensure that the FD model is not mis-specified. For instance, the correlation graph matrices for the first-differenced household expenditure and explanatory variables (including their interaction terms) did not find serious functional forms problems. Results of these graph matrices are displayed in Figure A5.1 that has all the assets and their interactions, and Figure A5.2 with only key assets, in Appendix A5, p.249. Potential nonlinearities in the data may have been adequately controlled for with the use of interaction terms. This observation was also confirmed by a series of regression diagnostics in form of 'lowess' and 'local linear' nonparametric regressions of each of the actual and log transformed productive asset per adult-equivalent relative to the respective sample mean, on household expenditure per adult-equivalent conditional on poverty line (See plots of these estimations in Figures A5.3-A5.10, Appendix 5, p.250-253). The individual graphs appear to suggest a largely log-linear relationship between each of the asset variables and household consumption expenditure. A pair-wise correlation matrix also indicated that independent variables and their interaction terms in the model are only weakly correlated, with the highest correlation coefficient noted to be 0.6261.

The FD results are summarized in Table 2, with estimates for the Cobb-Douglas (CD) model presented by specification1, while those of the translog model formulation (with interaction effects) are indicated by specifications 2 and 3. The values of F statistics are significant (at 1% level) in all the three model, but clearly higher (17.147) in the CD model than (7.670 – 8.876) in the case of the translog model specifications. Although, much of the variation in the consumption expenditure of households is not explained, the joint effect of the asset variables appears to be more pronounced in specification 1 of a pure CD production function.

Conversely, the estimated R-squared does not increase much from CD in specification 1 to the translog function in model specification 2 and 3. The value of R^2 is shown to be 18-19 percent. The potential effects of heteroskedasticity were controlled for by using the log transformed dependent and explanatory variables, in addition to the use of robust standard errors with adjustments to clusters in households. The mean values for the uncentered variance inflation factors (VIFs) for all the independent variables in each of the three model specifications were found to be low, 1.80-2.17, which indicates that there is no collinearity among the model covariates. The added asset interaction effects appear not to effect household expenditure substantially. This makes the CD model in specification 1 a preferred formulation to the translog model in this article. The potential nonlinearities and interaction effects are not strong enough to make translog formulation more superior than a CD formulation.

The estimated FD results in model specification 3 in Table 2 show that the interactive asset terms have insignificant coefficients, with exception of the two-way interaction between human capital and livestock that has a significant (at 10 percent level only) and negative coefficient of -0.38. This suggests that rural households can utilize their endowment of human capital and livestock as substitutes. Jointly though, the poverty impact of all the interacted terms of assets is found not to be significant. The F test result for the joint significance of interacted terms was found to be 0.85, with a p-value of 0.5306.

When it comes to the quadratic terms in the translog model, the coefficient on the quadratic term of livestock asset is shown to be weakly significant (10 percent level) with a negative coefficient. The joint poverty impact of the quadratic terms was equally found to be insignificant, with F test statistic value of 1.39 with a p-value of 0.2457. We may therefore reject the claim that there are significant interaction and non-linearity effects that the Cobb-Douglas model does not capture. However, a further test of this is made with the semi-parametric models that follow below.

The estimated FD results in Table 2 indicate that all factor assets have a positive and statistically significant effect on household consumption expenditure in the three model specifications. In the short term, access to additional operated land, human capital, livestock, and productive farm equipments relative to their respective sample mean is important in

explaining the level of household expenditure per adult-equivalent in relation to the poverty line. In the case of model specification 1, a one percent increase in the units of sample mean operated land per adult-equivalent increases the units of household poverty line expenditure per adult-equivalent by 0.22 percent, and this poverty reduction impact is significant at 5 percent level. This result shows that land access plays a significant role in the reduction of rural poverty, and concurs with the findings in the first paper of this thesis. Pender et al (2004) also shows that the lack of access to land and ownership of limited physical assets can affect the intensity of land management and rural poverty levels.

Access to human capital in model 1 of Table 2, has a significant (1 percent level) positive coefficient (0.77). This means that the consumption expenditure of rural households increase by approximately 0.77 percent of poverty line expenditure, when endowments of human capital increase by one percent of the sample mean. This is strong evidence on the importance of human capital (e.g. household investment in education and good health) in reducing poverty levels.

Results in model1 in Table 2 further show that the accumulation of livestock (*such as cows, ox, sheep, goats, pigs, donkeys, chicken birds, turkeys, ducks, and pigeons*) has a positive effect on household consumption expenditure that is significant at 1 percent level. For example, the welfare measure is shown to increase by approximately 0.27 percent with a one percent increase in sample mean value of livestock endowment. Noteworthy is that the poverty reduction impact of the change in the endowment of livestock appears to increase to 0.32, when the interaction terms especially that between livestock and human capital is included. The figures would have been bigger if the sample mean calculation included households with zero asset values.

In the case of the productive farm equipments, results in model 1 indicate a positive coefficient of 0.325 that is statistically different from zero at one percent level. Thus, the relative increase in the welfare measure is approximately 0.33 percent for every corresponding one percent increase in the sample mean value of farm equipments. The fact that farm equipments can be easily liquidated to generate quick cash in some cases, may probably explain the strong impact of farm equipments in boosting household consumption expenditure relative to the poverty line.

TABLE 2
ESTIMATES FOR POVERTY EFFECTS OF PRODUCTIVE FACTOR ASSETS BASED ON THE FIRST-DIFFERENCED MODEL, 2001-2005

	Differenced log real household expenditure per adult-equivalent normalized to poverty line		
Differenced independent variables normalized to sample mean level	1	2	3
Log operated land per adult-equivalent	0.220**	0.221**	0.215**
	(0.09)	(0.10)	(0.09)
Log household human capital per adult-equivalent	0.765***	0.736***	0.736***
	(0.18)	(0.18)	(0.18)
Log real value of livestock asset per adult-equivalent	0.267***	0.319***	0.317***
	(0.06)	(0.07)	(0.07)
Log real value of farm equipments per adult-equivalent	0.325***	0.263***	0.283***
	(0.09)	(0.10)	(0.10)
Log operated land x log human capital per adult-equivalent		0.008	0.065
		(0.34)	(0.34)
Log operated land x log value of livestock asset per adult-equivalent		0.014	0.116
		(0.10)	(0.11)
Log operated land x log value of farm equipments per adult-equivalent		-0.129	-0.175
		(0.13)	(0.16)
Log human capital x log value of livestock asset per adult-equivalent		-0.357*	-0.383*
		(0.21)	(0.22)
Log human capital x log value of farm equipments per adult-equivalent		0.424	0.355
		(0.34)	(0.36)
Log value of livestock x log value of farm equipments per adult-equivalent		0.014	0.061
		(0.10)	(0.11)
Log operated land per adult-equivalent, squared			-0.045
			(0.09)
Log real value of livestock asset per adult-equivalent, squared			-0.094*
			(0.05)
Log real value of farm equipments per adult-equivalent, squared			0.044
			(0.09)
Dummy variable 2003	-0.127**	-0.123*	-0.091
	(0.06)	(0.07)	(0.07)
Dummy variable 2005	-0.121*	-0.112	-0.067
	(0.07)	(0.08)	(0.09)
Household first-differencing (FD) model	Yes	Yes	Yes
Number of observations	606	606	606
F statistic	17.147	8.876	7.670
Prob > F	0.000	0.000	0.000
R-squared	0.179	0.185	0.189
Root Mean Square Error (RMSE)	0.820	0.822	0.822
Mean variance inflation factors (VIF), uncentered	1.80	1.86	2.17

Note: Standard errors are in parentheses; * Significant at 10%; ** significant at 5%; *** significant at 1%

The effect of dummy year periods may reveal the effect of technical change and other factors such as weather, prices and land degradation, in relation to the initial period of 2001. The negative significant coefficients for the year dummies in the Cobb Douglas model may be

associated with population increase or land degradation. However, they are also associated with the interaction and quadratic terms in the translog model and we should therefore not put too much emphasis on these results.

It is also important to note that the FD translog and Cobb Douglas production function models may suffer from time-variant endogeneity bias that could not be controlled for with the FD approach. However, the lack of valid instruments to predict each endogenous asset, and software limitations prevented us from applying an IV and systems approach that in theory could have resolved these endogeneity and simultaneity issues.

Results of the semiparametric additive model

The generalized additive semiparametric model (GAM) is explained in Appendix A. The estimated GAM model results of the two specifications are summarized in Table 3, but the main estimates of interest are shown in Figure 1, for the corresponding partial regression plots for each of the assets. The GAM model is claimed to be able to uncover the hidden structure of the relationship between the dependent variable and each of the discrete and continuous explanatory variables that is often missed in parametric models. In this analysis, the GAM model is specified with the individual assets and their interaction terms to match the main FD model, with exception of the quadratic terms. All the interactive terms were found to be insignificant when entered nonparametrically, implying that the pure additive model provides a reasonable fit to the data (Ruppert et al. 2003).

The insignificant interactive terms were then dropped in this analysis to estimate only the pure additive model specification 2. Conversely, when the interactive terms were modeled parametrically, only one interactive term for livestock and farm equipments *(lnlvstck_lnpfeqv)* was found to have a significant (1% level) and negative coefficient of -0.278. This may indicate that livestock and farm equipments are substitutes in the production process of households. Perhaps, this is related to the accumulation decisions that compel households to consume less to save more livestock for future consumption. The remaining insignificant interactive terms were dropped in model specification 1.

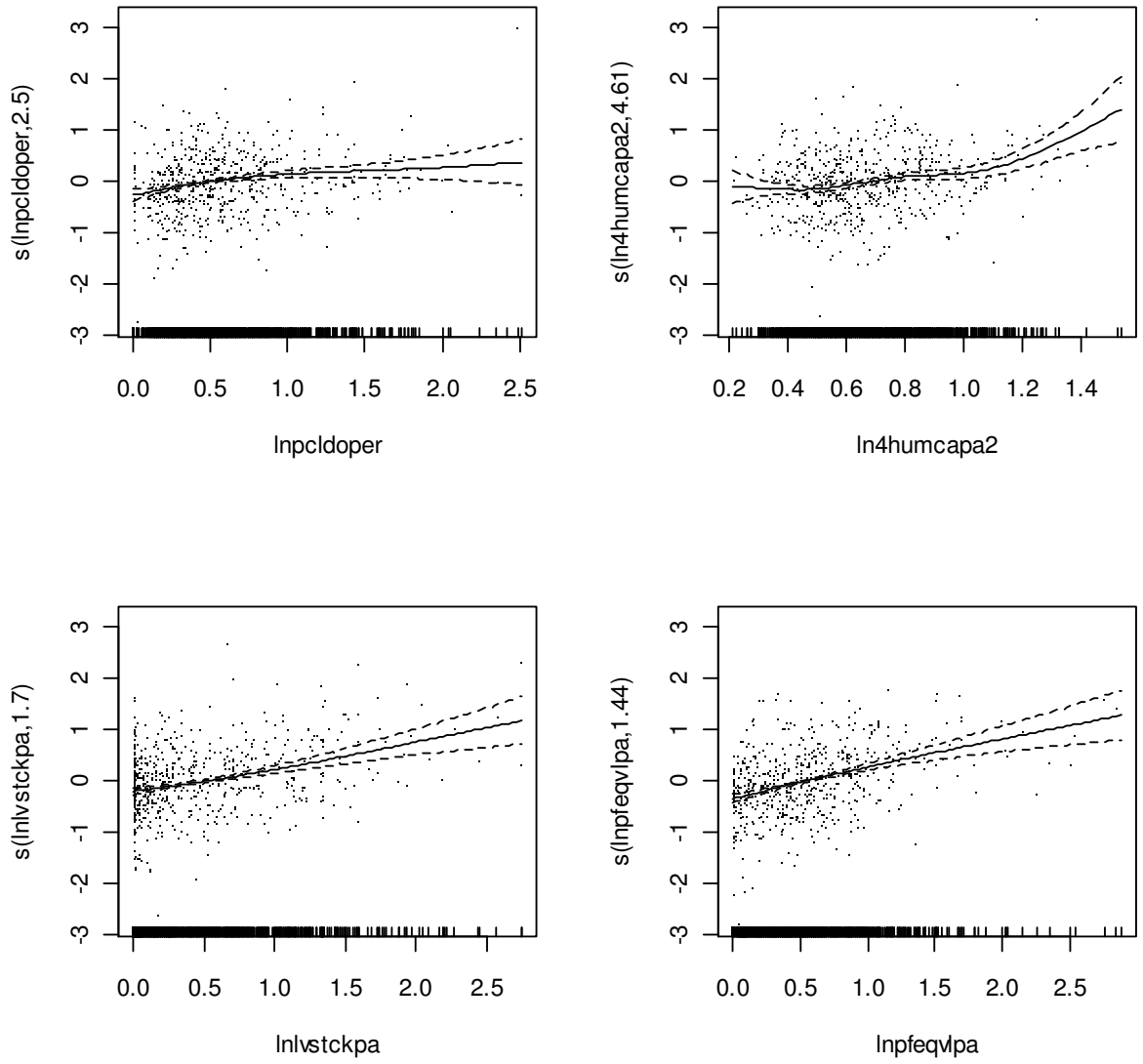
TABLE 3
ESTIMATES FOR POVERTY EFFECTS OF PRODUCTIVE FACTOR ASSETS BASED ON THE SEMIPARAMETRIC ESTIMATION (A GENERALIZED ADDITIVE (GAM) MODEL-OF THE "mgcv" PACKAGE

	Log real household expenditure per adult-equivalent normalized to poverty line *(lnnzpaq exp)*							
	Model specification1: (with an interaction term)				Model specification2: (without an interaction term)			
Independent variables normalized to sample mean level								
Family: gaussian	Yes				Yes			
Link function: identity	Yes				Yes			
Approximate significance of smooth terms:	*edf*	*Ref.df*	*F*	*p-value*	*edf*	*Ref.df*	*F*	*p-value*
Log operated land per adult-equivalent	2.500	3.172	9.755	1.41e-06 ***	2.361	2.997	10.747	6.15e-07 ***
Log household human capital per adult-equivalent	4.607	5.724	8.371	1.51e-08 ***	4.614	5.733	8.806	4.95e-09 ***
Log real value of livestock asset per adult-equivalent	1.704	2.149	20.036	9.66e-10 ***	1.000	1.000	33.564	9.54e-09 ***
Log real value of farm equipments per adult-equivalent	1.445	1.785	30.656	1.91e-12 ***	2.445	3.080	21.378	1.16e-13 ***
Parametric coefficients:	*Estimate*	*Std. Error*	*t value*	*Pr(>|t|)*	*Estimate*	*Std. Error*	*t value*	*Pr(>|t|)*
Intercept (Intercept)	0.20463	0.04605	4.443	9.96e-06 ***	0.11623	0.04005	2.903	0.00379 **
Log value of livestock x log value of farm equipments per adult-equivalent	-0.27798	0.07500	-3.706	0.000223 ***				
Dummy variable for year 2003	-0.08903	0.05579	-1.596	0.110856	-0.09432	0.05593	-1.686	0.09209 .
Dummy variable for year 2005	-0.07641	0.05913	-1.292	0.196627	-0.08826	0.05925	-1.490	0.13667
R-sq.(adj)				0.293				0.287
Deviance explained				30.4%				29.7%
GCV score				0.3861				0.389
Scale est.				0.38005				0.38326
Number of observations				909				909

Note:

i. Significance codes: * Significant at 10%; ** significant at 5%; *** significant at 1%
ii. Formula for model specification 1: lnnzpaqexp ~ s(lnpcldoper) + s(ln4humcapa2) + s(lnlvstckpa) + s(lnpfeqvlpa) + lnlvstck_lnpfeqv + factor(year)
iii. Formula for model specification 2: lnnzpaqexp ~ s(lnpcldoper) + s(ln4humcapa2) + s(lnlvstckpa) + s(lnpfeqvlpa) + factor(year)
iv. *"lnpcldoper"* denotes log operated land per adult-equivalent
v. "*ln4humcapa2" d*enotes log household human capital per adult-equivalent
vi. *"lnlvstckpa"* represents log real value of livestock asset per adult-equivalent
vii. "*lnpfeqvlpa"* signifies log real value of farm equipments per adult-equivalent
viii. "*year*" indicates year dummy variables
ix. "*lnlvstck_lnpfeqv"* Log value of livestock x log value of farm equipments per adult-equivalent

FIGURE 1
RESULTS OF THE GENERALIZED ADDITIVE SEMIPARAMETRIC ESTIMATION PARTIAL PLOTS ((The mgcv package)



Notes:

1. The dotted points represent the distribution of predicted residuals
2. The "mgcv" package of R-statistical program has the 'gam ()' function that estimates semi-parametric models, using penalized regression splines. The estimation of the smoothing parameter problem is based on the generalized cross validation (GCV) criterion, and the degree of smoothness of model terms.
3. In Table 3, "*edf*" represents *the* estimated model degrees of freedom for each smoothing term. It represents the trace of influence (or hat) matrix for the model fit. The estimated residual degrees of freedom '*Ref.df*' are computed as number of data minus model degrees of freedom. The "*edf*" for i[th] term can be defined as $tr\left(XP\_i\right)$ where X is the design matrix of the model and P_i denotes the matrix giving the parameters of the i[th] smooth when applied to data.
4. The "Scale est." denotes the estimated (or given) scale parameter. If the scale is positive then it is taken as the known scale parameter and unknown when it is negative.

As indicated in Table 3, model specification 1 has one extra parametric component of the interactive term for livestock and farm equipments, while model specification 2 is a pure additive model without any interaction term.

The adjusted R-squared (in Table 3) is shown to be 28.7- 29.3 percent and implies that a reasonable share of the variation in household welfare is explained by the included variables. The R-squared values in the GAM models are shown to be higher than in the case of the comparable parametric first-differenced Cobb Douglas and tranlog model specifications. This may be attributed to the ability of the GAM model to uncover all the potential nonlinearities in the data and to some extent the likely effects of time-invariant household heterogeneity that are less controlled for. The deviance explained in GAM model is also defined as the proportion of the null deviance explained by the model covariates, and is computed by taking into account of any offset. The deviance explained is shown to be 29.7 - 30.4 percent in the two GAM specifications. In addition, the Generalized Cross Validation (GCV) score is shown in Table 3 to be minimized at 0.386 - 0.389.

The partial fits (Figure 1) are based on the penalized linear splines for each productive asset variable, and concur pretty much with the main parametric estimates of the FD model. Like in the case of the primary estimates of the FD model, access to additional per adult-equivalent sample mean units of operated land, human capital, livestock, and productive farm equipments is found to have a positive and highly significant (1% level) impact on the household welfare measure. Each of the smoothing terms has effective degrees of freedom of 1.445 to 4.607 in the GAM model specification 1, and 1.00 to 4.614 in the GAM model specification 2, implying curvature. According to Ruppert et al. (2003), the curvature of the function is important in determining the number of degrees of freedom that is often greater than one for nonlinear terms and equal to one for linear terms. In order to provide reliable estimates of the smoothing terms, the S-PLUS additive model function “gam” avoids the challenges of automatic smoothing by defaulting to the amount of smoothing rule that starts with three degrees of freedom for each additive component.

The partial predictions in Figure 1 correspond to each of the productive asset variable in the GAM model. The estimated plots show the fitted marginal effect of the access to the productive asset variables on the horizontal axis as this asset varies across its observed range, while other variables are fixed at their respective observed means. The 95 percent confidence

bands are included in each graph based on the covariance matrix to make some allowance for the bias in the curve estimates (Ruppert et al. 2003). The wide confidence bands especially to the right reveal the fact that few households have access to this large asset endowment and consequently, the function is not accurately estimated in this region.

All the graphs demonstrate a significant and close to log-linear positive relationship between the four asset endowment variables and the household welfare measure. These are all significant at 1 percent level. It is evident that results on the assets did not change much, when the GAM model was estimated with and without the parametric interactive term of livestock and farm equipments. These results are in line with the findings of the FD model, and provide a clear confirmation that the main FD (Cobb Douglas and translog) model results are robust

VIII. CONCLUSION

This paper has investigated the joint contribution of four productive asset endowments to welfare improvement of households in rural Uganda by testing for alternative functional forms and possible asset interaction effects using Cobb-Douglas, translog, and semi-parametric specifications of the production function. Asset poverty has been identified as cause of low social welfare and poverty reduction policies may therefore have to focus on how to reduce asset poverty in order to improve welfare. Compared to urban areas, higher and persistent poverty levels in rural areas of Uganda raises considerable questions as to whether households can substantially benefit from their productive asset endowments to successfully get out of poverty through asset accumulation.

First-differencing (FD) was used to control for unobservable heterogeneity and time-invariant endogeneity in the parametric regressions. The findings of the FD method were then compared with estimates of the alternative semi-parametric statistical smoothing method in form of a generalized additive model (GAM). The findings from the FD and GAM model estimation indicate strong positive and significant relationships between changes in household welfare levels and changes in their asset endowment levels. Additional units of operated land, human capital, livestock, and productive farm equipments were found to reduce poverty in rural Uganda. The relative marginal poverty reduction impacts were significantly higher for human capital than for farm equipments, livestock, and operated land. Increasing land scarcity may limit the opportunities for land accumulation in densely

populated areas and cause a need for households to invest more in human capital as a poverty reducing strategy.

Only weak indications of significant asset interactions and deviations from log-linear asset-welfare relationships were found. This strengthens the confidence in the findings in the four papers that study one asset endowment at the time. The findings of this study suggest that accumulation of productive assets can be a good instrument for poverty reduction in rural areas. Particularly stimulation of accumulation of human capital may be a fruitful strategy for the government. Such policy interventions can aim to ensure schooling and on-job training opportunities, provide adequate health services, promote better functioning of land markets, provide credit for livestock accumulation, promote good livestock husbandry, and invest in reliable infrastructure to boost profitable market activities.

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Appendix A
Estimation of the Generalized Additive Semi-parametric Model (Using MGCV package)

This section describes the alternative generalized additive model (GAM) that is semi-parametric[56] and able to control for the potential nonlinearities. It was estimated as a robustness check of the FD findings, given its ability to produce a more adequate statistical fit that is in form of multiple smoothed terms and parametric coefficients of the poverty impact equation (6). There can be unknown level of non-linearities in the data, when several productive assets are considered together as independent, quadratic and interacting variables in the same estimating model. The GAM model allows one to specify a joint effect of linear predictors upon the dependent variable as the sum of individual smooth functions of the covariates. It can also have the conventional parametric component for some of the linear predictors.

The individual effects shows how the expected response variable varies when one of the predictors varies with other predictors held fixed at arbitrary values (Ruppert et al. 2003). Using R statistical software for data analysis, and the GAM command of the MGCV[57] package, the multiple smoothed terms of key asset variables relative to their respective sample means, and the parametric coefficients on interacting terms and time periods in equation (a1) were estimated. Four spline terms, each representing one of the four different sample mean asset variables per adult-equivalent were fitted as smooth (but otherwise unspecified) functions, while the corresponding 6 interacted terms and 3 quadratic asset variables were considered to be strictly parametric terms that entered the model linearly.

The model assumes data to be independently and identically distributed (i.i.d), although some level of heteroskedastic error process of unknown form is allowed (Li & Racine 2006). The effect of each explanatory variable on the joint mean response (on the log of poverty line

[56] A semi-parametric model has both the parametric and nonparametric components, but is able to avoid the curse of dimensionality by reducing the dimension of nonparametric component (Li and Racine, 2006).

[57] According to the R-documentation manual, the 'mgcv' implementation of 'gam' model represents the smooth functions using penalized regression splines. It also uses basis functions by default for these splines that are designed to be optimal, given the number basis functions used. The GAM model smoothness and the solution of the smoothing parameter is made using either the Generalized Cross Validation (GCV) criterion, $nD/(n-DoF)^{\wedge 2}$ or the Un-Biased Risk Estimator (UBRE) criterion, $D/n+2*s*DoF/n-s$ with D representing the deviance, n the number of data, s the scale parameter and DoF the effective model degrees of freedom. The UBRE is only used when s is known. In this case, smoothing parameters are chosen to minimize the GCV or UBRE/AIC scores for the model.

household consumption expenditure per adult-equivalent units) is assumed to be independent and additive in nature, although an interaction term can also be included. Even where the effects are not additive, parameters of the additive model can be considered to be sufficient in providing a reasonable approximation (Maindonald & Braun 2003). In particular, the GLM model employed in this study has an identity link, with a normal errors (Gaussian type of the distribution) of the response variable given the covariates (Ruppert et al. 2003), and therefore equivalent to the linear model[58]. The fitted semiparametric model is given by:

$$\begin{aligned}\ln y_{ht} = {} & \delta_0 + \delta_1 \Delta D_t + \mathrm{f}\left(\ln \mathrm{A}_{ht}\right) + \mathrm{f}\left(\ln \hat{H}_{ht}\right) + \mathrm{f}\left(\ln V_{ht}\right) + \mathrm{f}\left(\ln M_{ht}\right) \\ & + \mathrm{f}\left(\ln \mathrm{A}_{ht} * \ln \hat{H}_{ht}\right) + \mathrm{f}\left(\ln \mathrm{A}_{ht} * \ln V_{ht}\right) + \mathrm{f}\left(\ln \mathrm{A}_{ht} * \ln M_{ht}\right) \\ & + \mathrm{f}\left(\ln \hat{H}_{ht} * \ln V_{ht}\right) + \mathrm{f}\left(\ln \hat{H}_{ht} * \ln M_{ht}\right) + \mathrm{f}\left(\ln V_{ht} * \ln M_{ht}\right) \\ & + \mathrm{f}\left(\ln \mathrm{A}_{ht} * \ln \mathrm{A}_{ht}\right) + \mathrm{f}\left(\ln V_{ht} * \ln V_{ht}\right) + \mathrm{f}\left(\ln M_{ht} * \ln M_{ht}\right) + e_{ht} \quad t = 2..3, \;\; h = 1,2,..N \end{aligned} \qquad (\mathrm{a1})$$

where δ_0 is a scalar parameter, all model covariates are defined as explained in section 5 in the main text, δ_i is unknown parameter that indicates the level of technical change on dummy variables for time that also constitute the parametric part of the model. Explanatory variables that are specified in the unknown smooth functions $f(.)$ constitute the nonparametric part of the equation (a1) above.

[58] It is important to note that the standard instrumental variables and control function estimation procedures have recently been recommended to be extended to nonparametric and semiparametric estimation of variants of linear equation with endogenous regressors to further control for the endogeneity bias in the estimates (Blundell and Powell, 2003). However, estimation of panel data with nonparametric analysis based on these methods has not received much attention. The removal of the fixed factors responsible for the endogeneity bias is reported to make the semiparametric estimates invalid (Racine, 2009), unless the assumption of additively separable effects is allowed to hold. Besides, some of the recently proposed nonparametric panel methods that depend on; covariance structure of model disturbances, panel random-effects and additive fixed-effects are yet to be fully accepted.

TABLE A1
SAMMARY STATISTICS OF HOUSEHOLD WELFARE AND ASSET ENDOWMENT STATUS, 2001-2005 (N=909)

	With zero observations			Without zero observations			
Variable description	No	%	Mean	Mean	sd	min	max
Household income per adult-equivalent/10,000) (Ug.shs)	7	0.77	31.08	31.32	42.97	0.04	478.98
Household expenditure per adult-equivalent/10,000) (Ug.shs)	0	0.00	37.05	37.05	46.21	1.07	1072.17
Household income per time-average adult-equivalent/10,000) (Ug.shs)	7	0.77	29.02	29.25	39.17	0.03	322.53
Household expenditure per time-average adult-equivalent/10,000) (Ug.shs)	0	0.00	34.73	34.73	34.81	0.85	609.26
The national poverty line per person per year, at 2005 prices (Ug.shs)	0	0.00	261717.10	261717.10	0.00	261717.10	261717.10
Land owned per adult-equivalent (acres)	28	3.08	1.08	1.11	1.43	0.00	13.19
Land operated per adult-equivalent (acres)	17	1.87	1.16	1.18	1.41	0.02	13.44
Land per adult-equivalent brought in through renting, borrowing & purchases (acres)	245	26.95	0.59	0.81	1.14	0.00	13.14
Land per adult-equivalent brought in through renting & purchases (acres)	296	32.56	0.55	0.81	1.17	0.00	13.14
Land inherited per adult-equivalent (acres)	360	39.60	0.42	0.70	0.83	0.01	6.19
Value of human capital at a household level (Ug.shs)	0	0.00	405089.30	405089.30	297630.10	44734.91	2922461.00
Value of human capital per-adult-equivalent/10000 (Ug.shs)	0	0.00	6.40	6.40	2.99	1.53	23.18
Average years of education/schooling for all household members	15	1.65	4.62	4.70	2.25	0.14	14.00
Annual earnings of adult individuals aggregated at household level (Ug.shs)	0	0.00	819905.50	819905.50	1215367.00	11754.39	11700000.00
Household members that passed away (died) in a year	786	86.47	0.18	1.36	0.70	1.00	4.00
Number of days sick individuals were unable to work normally	342	37.62	31.41	50.36	76.20	1.00	600.00
Number of sick days per adult-equivalent	342	37.62	6.27	10.04	15.28	0.16	93.50
Number of children below 10 years of age	148	16.28	2.44	2.92	1.65	1.00	10.00
Adult-equivalent of children below 10 years of age	148	16.28	1.49	1.78	1.06	0.23	8.67
Tropical livestock units (TLUs) per adult-equivalent	98	10.78	0.25	0.28	0.38	0.00	2.78
Livestock asset value per adult-equivalent/10000 (Ug.shs)	98	10.78	8.80	9.86	15.67	0.02	143.85
Value of productive equipments per adult-equivalent/10000 (Ug.shs)	38	4.18	1.85	1.93	2.81	0.01	32.31
Value of livestock & farm equipments per adult-equivalent/10000 (Ug.shs)	8	0.88	10.65	10.74	16.36	0.01	150.66

Note: (i) All household income, expenditure, and asset variables per adult-equivalent are in real values at 2005 price level; (ii) Livestock and TLU[59] equivalent are cows = 0.5, ox = 0.5, sheep = 0.10, goats = 0.10, pigs = 0.20, donkeys = 0.5, chicken birds = 0.01, other birds (turkey, ducks and pigeons) = 0.03, and rabbits = 0.20; (iii) Productive farm equipments include: plough-sets, horse/donkey carts, wheelbarrows, boreholes, spray pumps, brewing trough, distilling equipment, fish nets, diesel pumps, water tanks, beehives, trailers, grinders, axe, pangas, slathers, hand hoes, spades, storage facility, water tanks, bicycle, and radio.

[59] We computed Tropical Livestock Unit (TLU) equivalent for livestock species based on FAO weights for sub-Saharan Africa (See Jahnke (1982); the Compendium of Agricultural-Environmental indicators 1989-91 to 2000, Statistics Division, FAO, November, 2003).

Extended Appendix (A1-A5)

This extended appendix presents tests for endogeneity of different productive assets and other explanatory variables. It also Shows alternative diagnostic tests of linear functional forms and other relevant information in this study.

APPENDIX A1 (RELEVANT FOR PAPER 1 IN THE MAIN TEXT)

The graphs A1- A7 tests whether there are nonlinearities between household expenditure and each of the actual (and residual) land access variables.

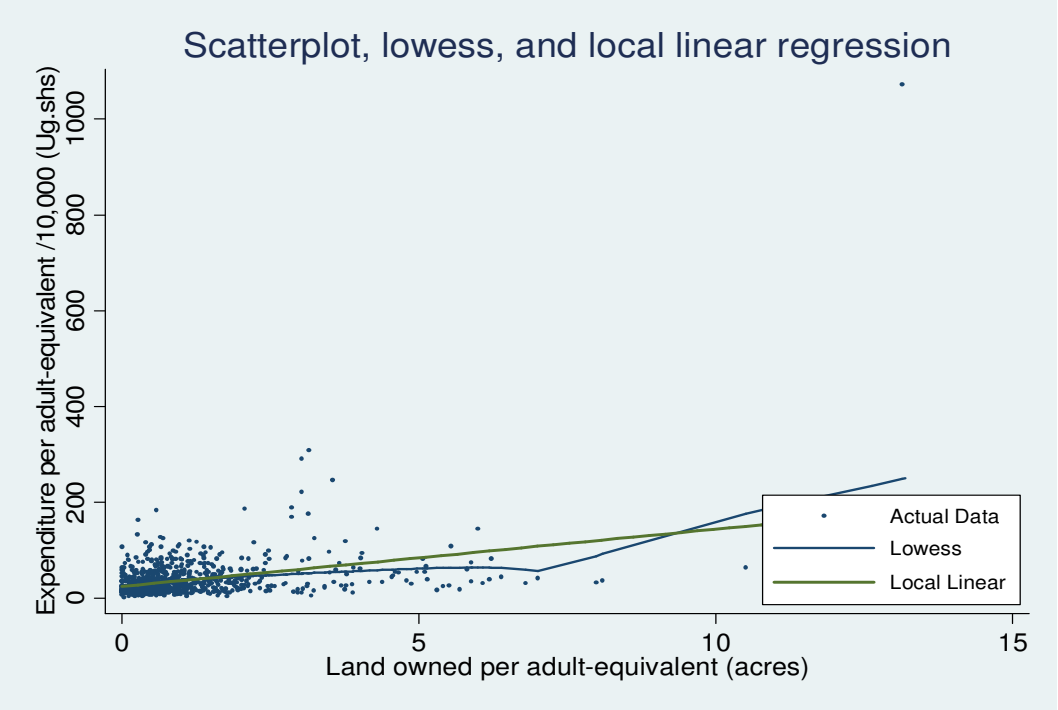


Figure A1.1. Scatterplot and nonparametric regression between owned land per adult-equivalent (acres) and household expenditure per adult-equivalent (Ug.shs)

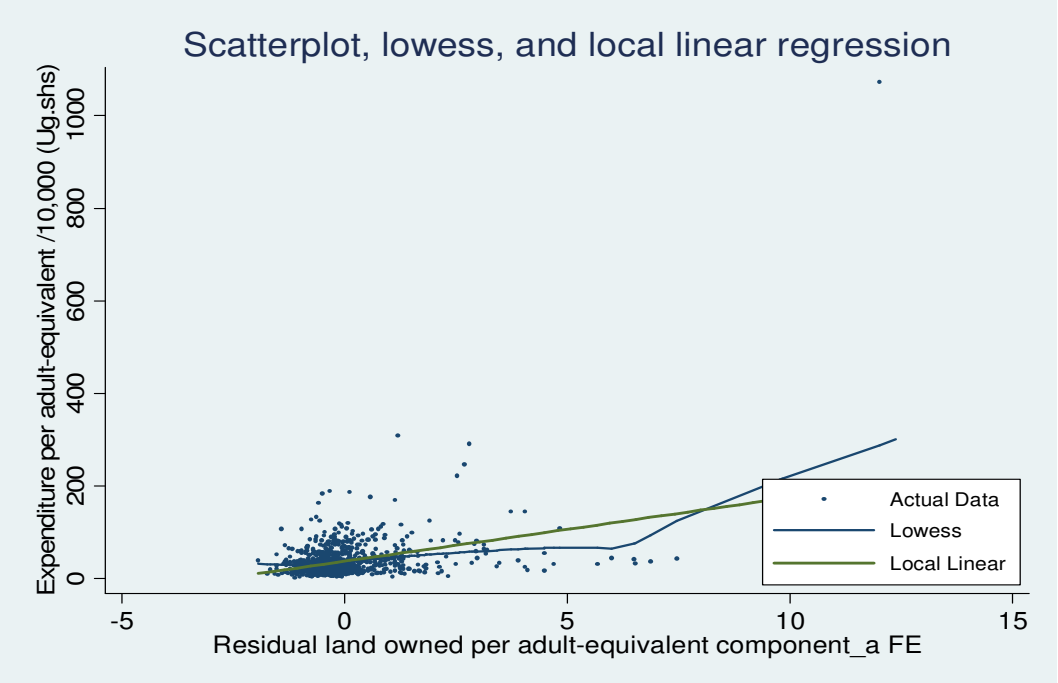


Figure A1.2. Scatterplot and nonparametric regression between the residual owned land per adult-equivalent (acres) and household expenditure per adult-equivalent (Ug.shs)

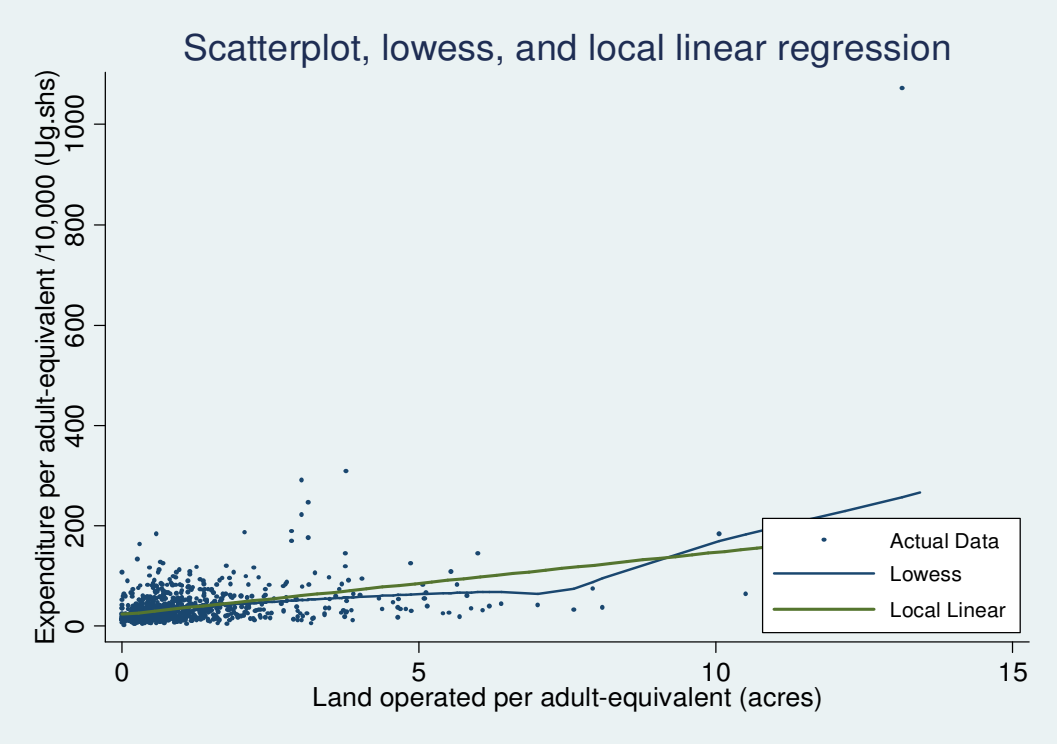


Figure A1.3. Scatterplot and nonparametric regression between operated land per adult-equivalent (acres) and household expenditure per adult-equivalent (Ug.shs)

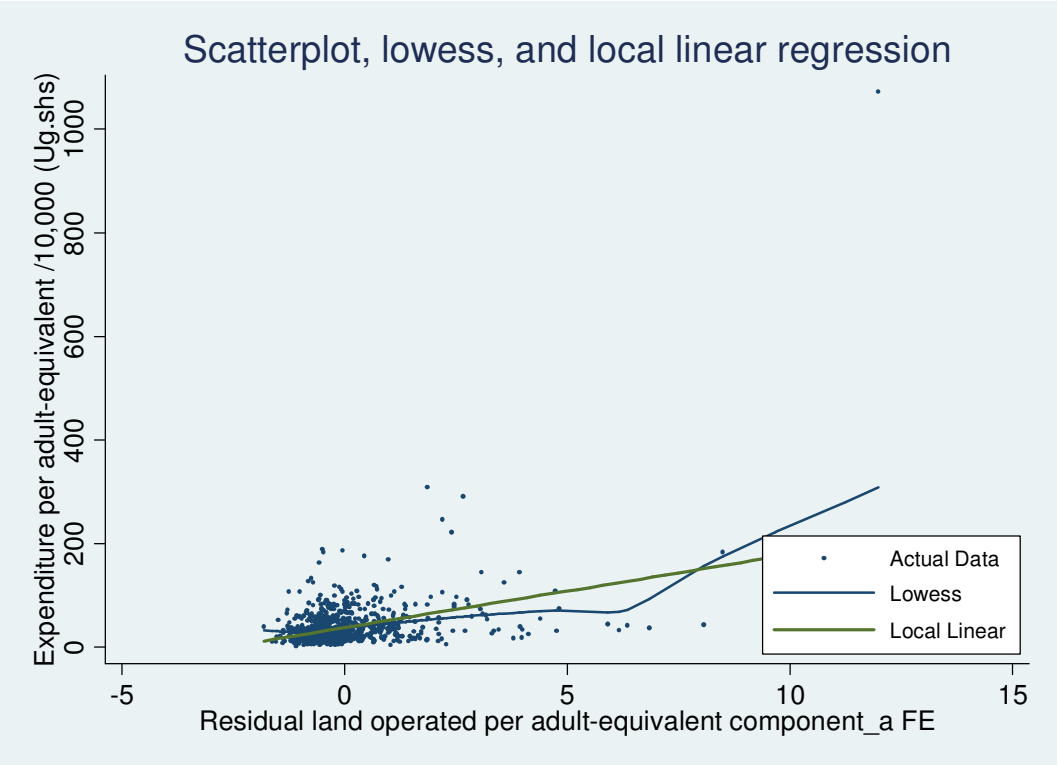


Figure A1.4. Scatterplot and nonparametric regression between the residual operated land per adult-equivalent (acres) and household expenditure per adult-equivalent (Ug.shs)

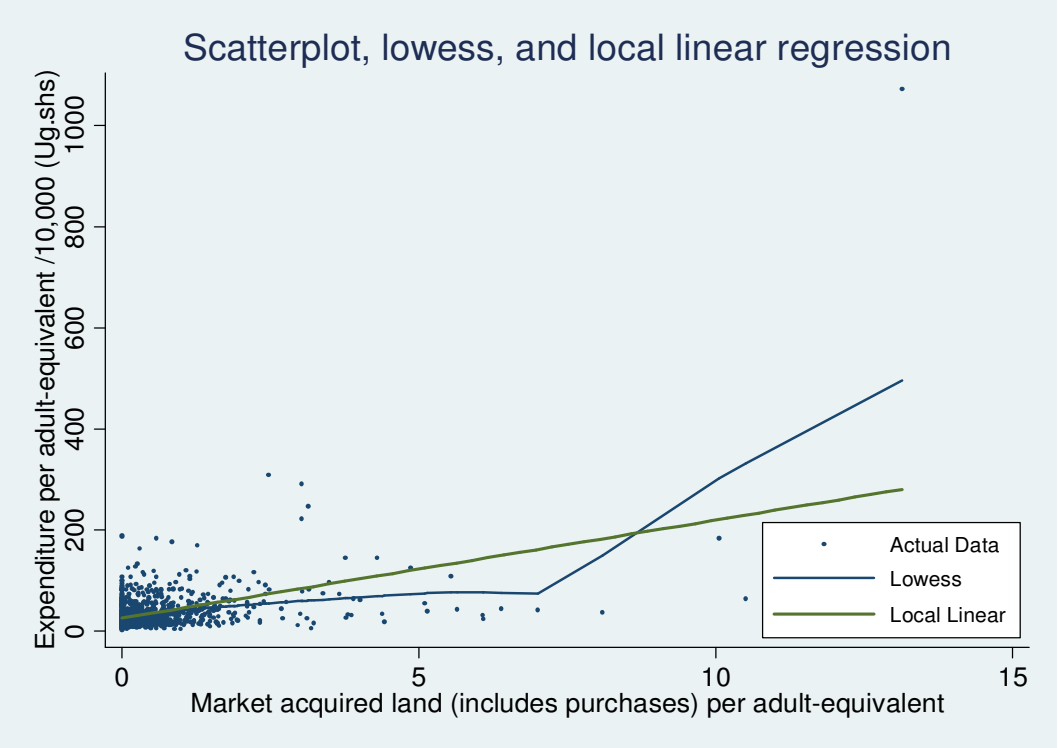


Figure A1.5. Scatterplot and nonparametric regression between market acquired land per adult-equivalent (acres) and household expenditure per adult-equivalent (Ug.shs)

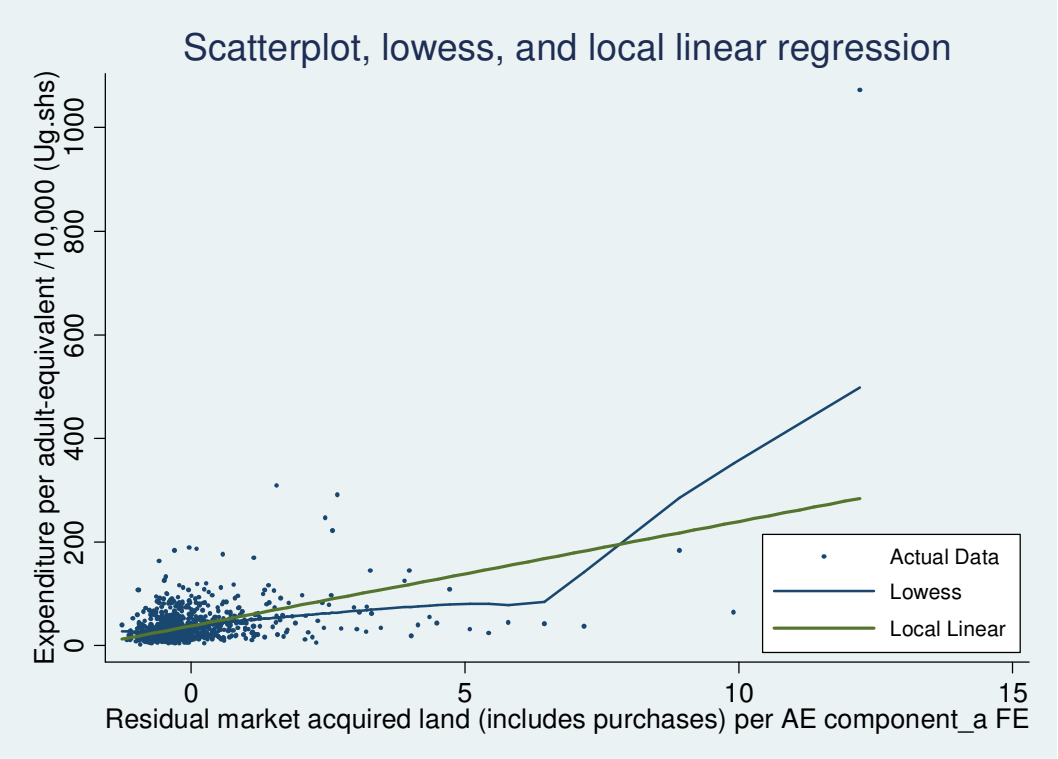


Figure A1.6. Scatterplot and nonparametric regression between the residual market acquired land per adult-equivalent (acres) and household expenditure per adult-equivalent (Ug.shs)

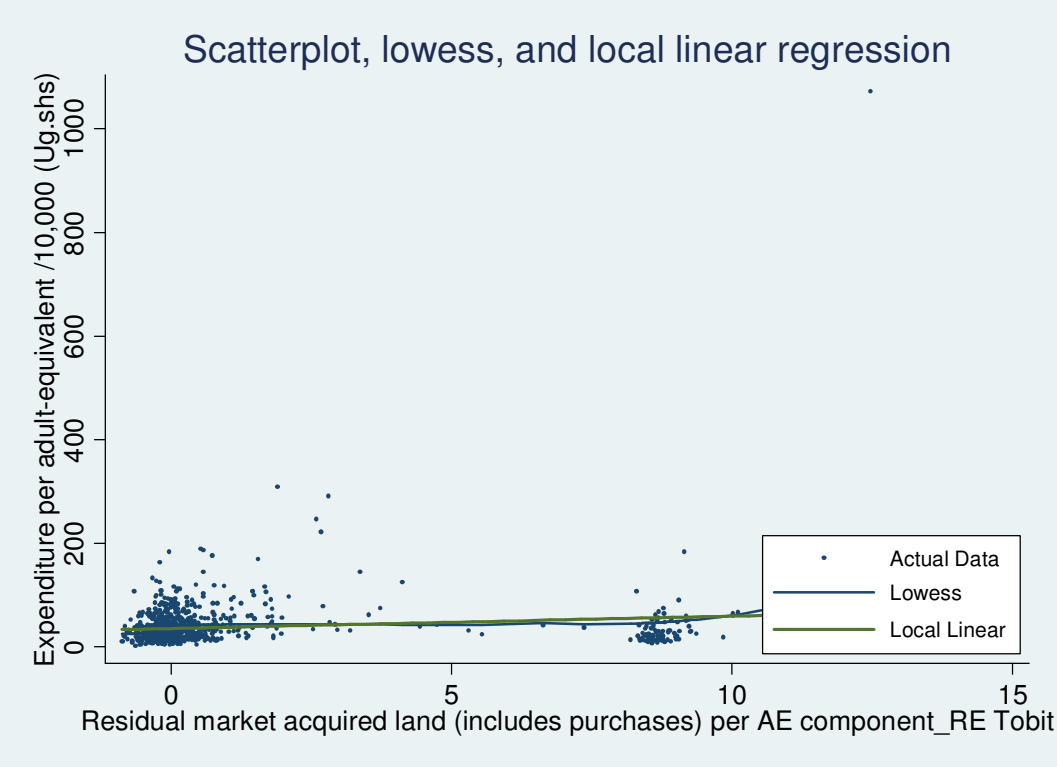


Figure A1.7. Scatterplot and nonparametric regression between the residual market acquired land per adult-equivalent (acres) and household expenditure per adult-equivalent (Ug.shs).

N.B: The concentration of observations at two locations can be attributed to the use of nonlinear model (i.e. the dynamic random-effects Tobit Model) in the first-stage, and the fact that variables are not log transformed to ensure symmetry.

APPENDIX A2 (RELEVANT FOR PAPER 2 IN THE MAIN TEXT)

The variable of household size is considered to be endogenous to the household consumption decisions. Here (Table A2.1), the panel random-effects model is employed to predict the log of household adult-equivalent that is then employed in the estimation of the poverty impact equation. Table A2.2 presents results of the first-stage estimation of the robustfied Durbin-Wu-Hausman (DWH) method (see Cameron and Trivedi (2010)) that tests for endogeneity bias for human capital & number of sick-days variables. The second-stage test results of the DWH are summarized in Table A2.3 and show that only human capital is endogenous to household consumption decisions.

Table A2.1
Estimation of the predicted log of household size, a household random-effects model

	Log of household size in adult-equivalent	
	Only members >=10 years	All members of all ages
Independent variables	1	2
Age of spouse of household head (Years)	0.056***	0.053***
	(0.01)	(0.01)
Age of spouse of household head squared (Years)	-0.001***	-0.001***
	(0.00)	(0.00)
Proportion of households that can afford at least 2 meals a day	0.100*	0.147***
	(0.06)	(0.05)
Members of the household that passed away (died) in a year	0.095***	0.061*
	(0.04)	(0.04)
Gini coefficient by district of land owned per adult-equivalent	-0.325	-0.513***
	(0.20)	(0.19)
Dummy variable for year 2001	0.319***	0.264***
	(0.05)	(0.05)
Dummy variable for year 2003	-0.022	-0.039*
	(0.02)	(0.02)
Constant	0.293*	0.814***
	(0.17)	(0.16)
Household random effects	Yes	Yes
Number of observations	912	912
Number of households	304	304
Wald chi2	162.746	114.456
Prob > chi2	0.000	0.000
R2-within	0.087	0.077
R2-between	0.252	0.211
R2-overall	0.167	0.143
Panel-level standard deviation (sigma_u)	0.232	0.230
Standard deviation of error term (sigma_e)	0.453	0.428
Panel fraction of variance (rho)	0.208	0.225

Note: Bootstrap (399) replications) standard errors are in parentheses. * Significant at 10%; ** significant at 5%; *** significant at 1%

Table A2.2 .First-step results of the Robustified Durbin-Wu-Hausman (DWH) endogeneity test for human capital & number of sick-days

		Log sick days	
	Log human capital	Number	Per adult-equivalent
Independent variables	1	2	3
Sex of the household head (1 = Male, 0 = Female)	0.084	-0.032	-0.083
	(0.06)	(0.27)	(0.20)
Dummy for deaths in a year (1 = household lost a person, 0 otherwise)	0.102***	0.260	0.182
	(0.04)	(0.22)	(0.17)
Log of predicted household adult-equivalent (size)	-0.067	2.080**	1.093
	(0.08)	(0.93)	(0.74)
Other in-kind non-land assets/1000 (Ug.shs) brought in by head and spouse at the start of household	0.000**	-0.000	0.000
	(0.00)	(0.00)	(0.00)
Age household head got married (years)	-0.003**	-0.016	-0.007
	(0.00)	(0.02)	(0.02)
Age of household head's spouse got married (years)	0.004*	0.007	0.012
	(0.00)	(0.02)	(0.02)
Land brought in by head and spouse at the start of household (acres)	0.002**	0.012***	0.006*
	(0.00)	(0.00)	(0.00)
Proportion of households that can afford at least 2 meals a day	-0.068	-0.250	-0.150
	(0.05)	(0.28)	(0.22)
Distance to primary market (miles)	-0.015**		
	(0.01)		
Dummy variable for high rainfall (1= bi and uni high, 0= otherwise)	0.080***		
	(0.03)		
Age of household head (Years)		0.017	-0.002
		(0.02)	(0.02)
Age of household head squared (Years)		0.000	0.000*
		(0.00)	(0.00)
Age of spouse of household head (years)		-0.088	-0.099**
		(0.06)	(0.05)
Age of spouse of household head squared (years)		0.001	0.001**
		(0.00)	(0.00)
Distance to the nearest local dispensary/clinic (miles)		0.014*	0.008
		(0.01)	(0.01)
Dummy variable for year 2001	-0.537***		
	(0.04)		
Dummy variable for year 2003	-0.143***	0.643***	0.421***
	(0.03)	(0.11)	(0.09)
Constant	2.041***	0.557	1.446**
	(0.15)	(0.67)	(0.56)
Pooled OLS estimation	Yes	Yes	Yes
Number of observations	912	608	608
F-statistic	35.899	10.274	6.739
Prob > F	0.000	0.000	0.000
R-squared	0.313	0.113	0.103
Adjusted R-squared	0.303	0.092	0.082
Root MSE	0.368	1.261	0.996

Note: (i) Bootstrap (399) replications) robust standard errors are in parentheses. * Significant at 10%; ** significant at 5%; *** significant at 1%.

Table A2.3
Second-step results of endogeneity test (for human capital, number of sick-days, and number of sick-days per adult-equivalent) based on the Robustified Durbin-Wu-Hausman (DWH) method

	Log of real household expenditure per adult-equivalent/10,000 (Ug.shs)		
Independent variables	1	2	3
Log of household human capital per adult-equivalent/10000 (Ug.shs)	1.525***		
	(0.30)		
Log days sick household members were unable to work normally		-0.152	
		(0.13)	
Log sick-days per adult-equivalent in a household			-0.075
			(0.14)
Sex of the household head (1 = Male, 0 = Female)	0.149	0.225*	0.245*
	(0.10)	(0.13)	(0.14)
Log of predicted household adult-equivalent (size)	-0.269	-0.326	-0.486**
	(0.17)	(0.25)	(0.21)
Dummy for deaths in a year (1 = household lost a person,	-0.161**	0.056	0.031
0 otherwise)	(0.08)	(0.10)	(0.10)
Dummy variable for year 2001	0.816***		
	(0.17)		
Dummy variable for year 2003	0.118	-0.020	-0.086
	(0.08)	(0.10)	(0.08)
Residual variable for endogeneity test	-1.073***	0.156	0.129
	(0.30)	(0.13)	(0.14)
Constant	0.696	4.159***	4.114***
	(0.73)	(0.39)	(0.47)
Pooled OLS estimation	Yes	Yes	Yes
Number of observations	912	608	608
F-statistic	11.933	2.549	2.659
Prob > F	0.000	0.019	0.015
R-squared	0.097	0.022	0.025
Adjusted R-squared	0.090	0.012	0.015
Root MSE	0.699	0.745	0.744

Note: (i) Bootstrap (399) replications) robust standard errors are in parentheses. * Significant at 10%; ** significant at 5%; *** significant at 1%.

In order to confirm whether sick-days variables can indeed be modeled as exogenous variables in this study, a Hausman test was conducted to verify whether the use of OLS model as opposed to the standard 2SLS gives consistent parameters. The Hausman test chi-square statistics were found to be insignificant as indicated in Table A2.4 (below), and are in line with the DWH test (above). We do not reject the null hypothesis that the OLS estimator is consistent for sick-days

Table A2.4
Results of endogeneity test for sick-days, a Hausman test for consistency of 2sls versus OLS models

	2SLS (IV)	OLS	2SLS (IV)	OLS
Independent variables	1a	1b	2a	2b
Log number of days, sick household members were unable to work	-0.183	-0.003		
	(0.13)	(0.02)		
Log number of sick-days per adult-equivalent, Members were unable to work			-0.178	0.048
			(0.17)	(0.03)
Sex of the household head (1 = Male, 0 = Female)	0.216*	0.273**	0.206	0.293**
	(0.13)	(0.11)	(0.14)	(0.11)
Dummy for deaths in a year (1 = household lost a person, 0 otherwise)	0.065	0.013	0.057	-0.000
	(0.11)	(0.10)	(0.12)	(0.10)
Log of predicted household adult-equivalent (size)	-0.299	-0.455**	-0.527**	-0.438**
	(0.24)	(0.20)	(0.22)	(0.20)
Dummy variable for year 2003	-0.000	-0.115*	-0.044	-0.136**
	(0.10)	(0.06)	(0.09)	(0.06)
Constant	4.206***	3.927***	4.374***	3.801***
	(0.40)	(0.33)	(0.56)	(0.34)
Number of observations	608	608	608	608
Wald chi2	2.557	2.373	2.389	2.893
Prob > F	0.027	0.038	0.037	0.014
R-squared	.	0.019	.	0.023
Adjusted R-squared	.	0.011	.	0.015
Root mean squared	0.780	0.745	0.778	0.743
Hausman test				
Hausman test: Chi2 statistics	2.17	2.17	1.94	1.94
Hausman test: Prob>chi2	0.1407	0.1407	0.1631	0.1631

Several diagnostic regression tests in form of scatter plots, nonparametric lowess and local linear regressions were conducted to verify whether there are nonlinearities in the data. Figures A2.1-A2.4 indicates linear relationship between log transformed household expenditure and each of the log transformed actual (and residual) human capital and sick-days variables

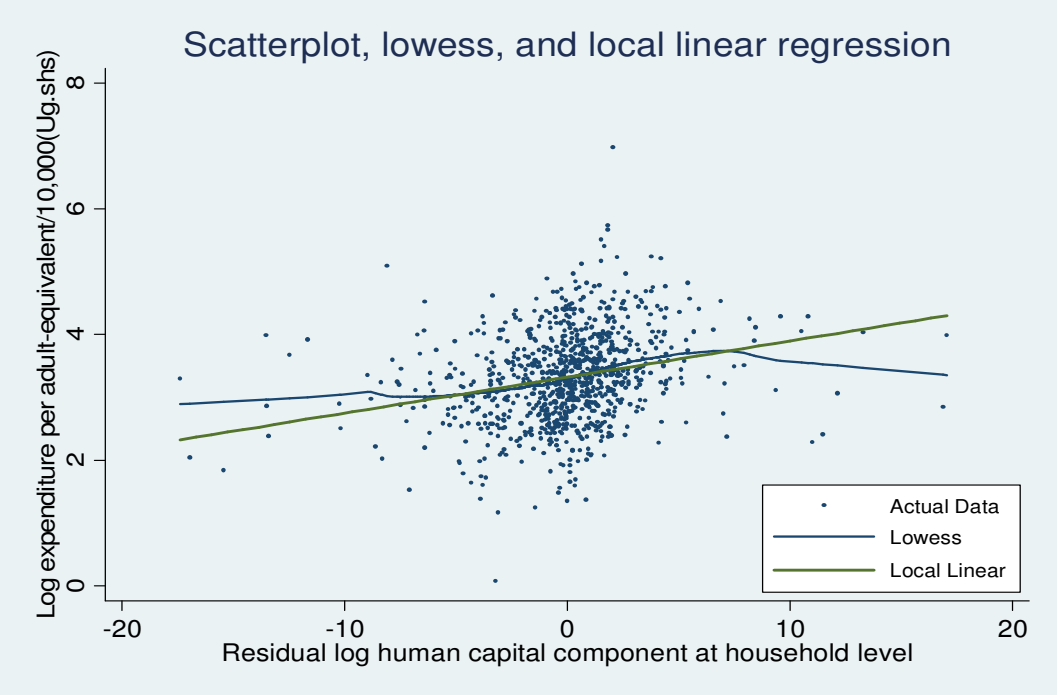


Figure A2.1. Scatterplot, lowess, and local linear fits for log of expenditure plotted against log of human capital residual component at a household level

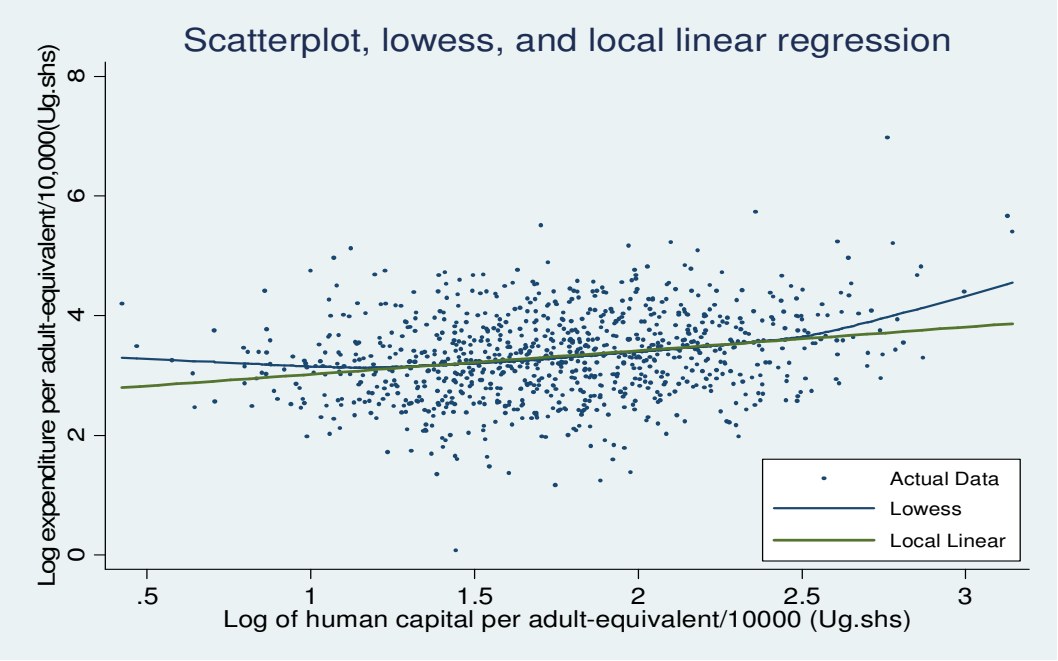


Figure A2.2. Scatterplot, lowess, and local linear fits for log of expenditure plotted against log of human capital per adult-equivalent

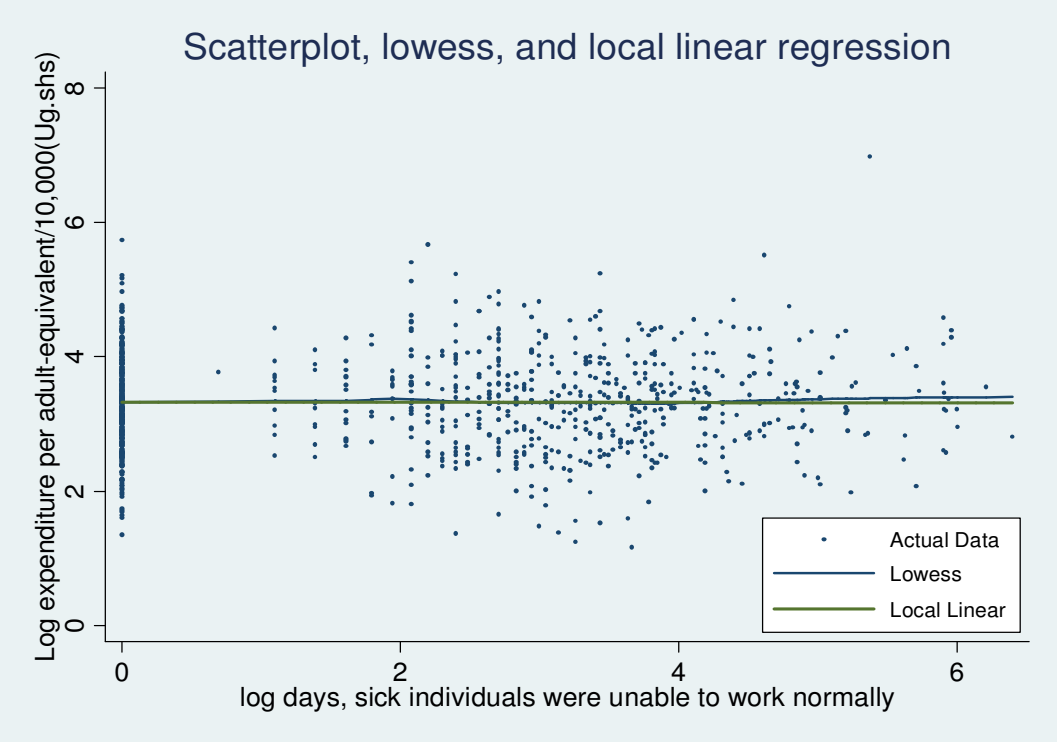


Figure A2.3. Scatterplot, lowess, and local linear fits for log of expenditure plotted against log of sick-days

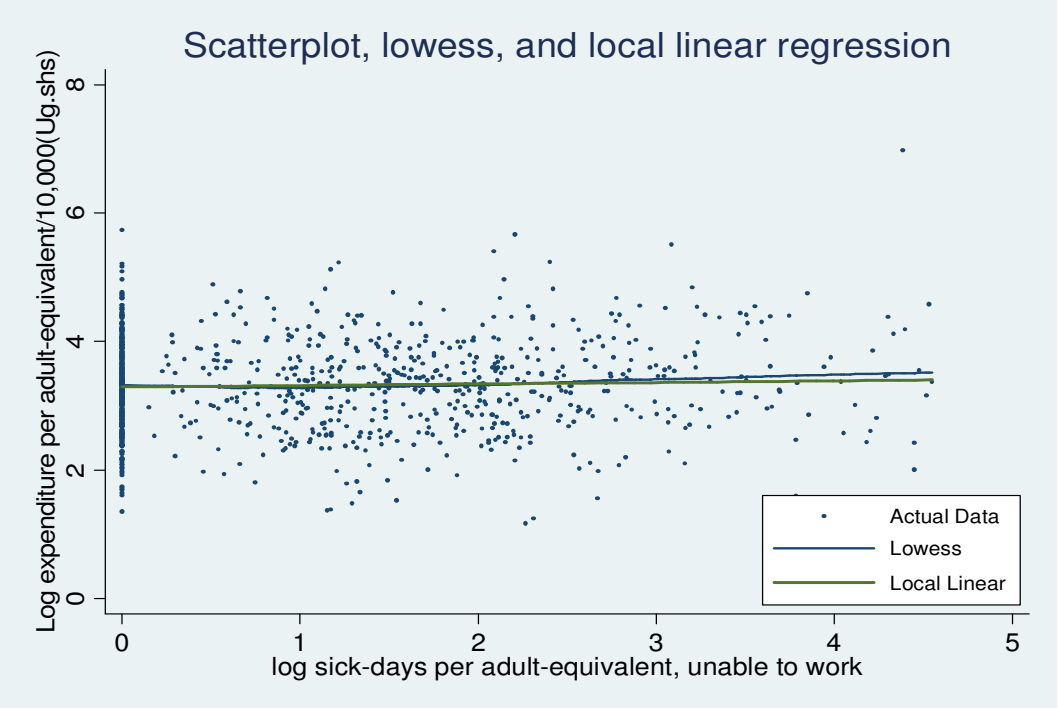


Figure A2.4. Scatterplot, lowess, and local linear fits for log of expenditure plotted against log of sick-days per adult-equivalent

APPENDIX A3 (RELEVANT FOR PAPER 3 IN THE MAIN TEXT)

Computation of Human Capital at Household Level

We employed the income based approach[60] that utilizes earnings of adult individual to estimate human capital. Individual earnings are assumed to be influenced by acquired skills and education level. Individual annual earnings for adult members working in seasonal business and wage labour activities were computed from their monthly wages and seasonal gross earnings, also defined as sales net of seasonal costs. However, it is not possible to observe earnings for adult household members that are self-employed on farm. Shadow earnings of these adult individuals were computed as the marginal earning from the joint household production value in each year, based on the Cobb-Douglas production function that was estimated as in the case of (Kurosaki and Khan, 2006, Yang, 1997) in equation a1 (below).

$$\ln Q_{ht} = \alpha_0 + \beta Z_{ht} + \delta \ln L_{ht} + \lambda D_{ht}^{L} + \eta \ln I_{ht} + \eta \ln F_{ht} + \mu D_{rt} + \psi D_t + c_h + \varepsilon_{ht} \qquad \text{(a3.1)}$$

where Q_{ht} denotes real value of total crop production in a year, Z_{ht} is a vector of household characteristics that include age of the household head, age of the household head squared, and sex of the household head, L_{ht} represents a vector of family labour force including adult male labour force, adult female labour force, and child labour force that was employed on-farm crop production, D_{ht}^{L} denotes a vector of dummy variables that control for scarcity of agricultural labour force in the context of male, female, and child family labour. Variable I_{ht} represents a vector of other inputs including real cash expenditure on hiring labour/draft animals service, real value of seeds/planting material, and real value of fertilizer use, while F_{ht} denotes operated farm size, D_{rt} represents the three regional dummies, D_t represents year effects in form of dummy variables for time periods, c_h is the unobserved effect that is controlled for with household random effects, ε_{ht} is the error term. The model (See results in Table A3.1, p.230) was estimated on a balanced panel data with household random effects (RE), following results of the Hausman

[60] Human capital can be measured using three closely related methods: the cost-based approach, income based approach, and educational stock-based approach (Le et al. 2003).

test (*chi2 = 12.69, and Prob>chi2 = 0.5511*) that failed to reject the null hypothesis, implying that the coefficients derived from RE and FE models are both consistent and similar. Human capital was computed based on the Mincerian earnings function presented in equation (a3.2) as defined in the work of Mincer (1974), and Krueger and Lindahl (2001). The Mincerian earning function specifies a linear relationship between the logarithm of earnings for individuals and the years of schooling, with the slope of this relationship interpreted as the rate of return to investment in schooling. Using unbalanced panel data of working age individuals that are 16 years and above, individual FE panel method was employed to compute predicted individual human capital and the residual human capital component.

$$\ln E_{it} = X_{it}\beta_i + V_{vt}\lambda_i + D_t\alpha_i + c_i + e_{it} \qquad \text{(a3.2)}$$

where E_{it} denotes wage level or annual earnings for individual i working either on farm or off-farm activities in year t, X_{it} denotes a vector of individual attributes such as education level and age, V_{vt} is the vector of village level characteristics like access to education facilities, health facilities, market access, population density and agricultural potential, D_t represents year effects in form of dummy variables for time periods, c_i is the unobserved effect that is controlled for with individual FE, e_{it} is the error term. Two alternative models were also estimated with RE method, to assess the sensitivity of computed human capital with different variable combination. Results of human capital estimation are derived from FE model specification 3*, Table A3.2 (below). The predicted individual human capital was collapsed or aggregated at household level. Let $\ln \hat{H}_{ht} = \ln \hat{E}_{ht}$ and $\ln H_{ht} = \ln E_{ht}$ at household level. The residual log component variable for human capital $\left(\ln H_{ht} - \ln \hat{H}_{ht}\right)$ was derived as the difference between the actual $(\ln H_{ht})$ and predicted annual earnings $(\ln \hat{H}_{ht})$ at the household level. Unlike the predicted instruments of human capital, the residual human capital component variable is not contaminated with spurious correlations due to unobserved heterogeneity.

Table A3.1. Estimation of the Cobb-Douglas production function, using a balanced panel data, a random-effects model to derive shadow earnings for household adult members that are self-employed on farm

	Log of real value of total crop production (Ug.shs) in a year (Value added)		
Independent variables	b	se	Xmfx_dydx
Age of the household head (yrs)	0.008	(0.017)	0.008
Age of the household head (yrs) squared	-0.000	(0.000)	-0.000
Sex of the household head (Male =1 Female = 0)	0.051	(0.131)	0.051
Log of male labor force on-farm crop production	0.308***	(0.103)	0.308
Log of female labor force on-farm crop production	0.177	(0.124)	0.177
Log of child labor force on-farm crop production	0.267***	(0.088)	0.267
Dummy for on-farm male labor force 1= low/scarce, 0=otherwise	0.301**	(0.129)	0.301
Dummy for on-farm female labor force 1= low/scarce, 0= otherwise	-0.024	(0.122)	-0.024
Dummy for on-farm child labor force 1= low/scarce, 0=otherwise	0.049	(0.109)	0.049
Log of real expenditure on hired labor & draft animal service (Ug.shs)	0.039***	(0.008)	0.039
Log of real value of seeds/planting material a year (Ug.shs)	-0.003	(0.008)	-0.003
Log of real value of fertilizer use in a year (Ug.shs)	0.040***	(0.014)	0.040
Log of farm size (acres)	0.468***	(0.050)	0.468
Dummy variable for region2 (Eastern Uganda)	-0.005	(0.087)	-0.005
Dummy variable for region3 (Western Uganda)	0.110	(0.101)	0.110
Dummy variable for year 2001	-0.844***	(0.130)	-0.844
Dummy variable for year 2003	-0.290***	(0.062)	-0.290
Constant	11.648***	(0.528)	
Household random effects	YES		
Number of observations	912		
Number of households	304		
Chi2 statistic	337.477		
Prob > chi2	0.000		
R2-within	0.245		
R2-between	0.379		
R2-overall	0.303		
Panel-level standard deviation	0.332		
Standard deviation of error term	0.968		
Rho (Panel fraction of variance)	0.106		
Hausman test statistic (Prob>chi2 = 0.5511)	12.69		

Note: (i) Bootstrap (399 replications) standard errors are in parentheses. * Significant at 10%; ** significant at 5%; *** significant at 1% , (ii) We decided to estimated the Cob-Douglas production using random effects panel method, after a Hausman test failed to reject the null-hypothesis The coefficients are consistent and unbiased whether we employ random effect or fixed effects approaches.

We find that estimated coefficients on main family labor input are positive and significant at 1% level for male and child labor force but insignificant for female lab or force. Thus, a 1% increase in the quantity of male, and child labor force increases farm revenues by 0.308% and 0.267% respectively. On the other hand a 1% increase in hired labor and draft animal service increases farm revenues by only 0.039%, which is lower compared to the estimated elasticities of family labor input. Overall, female labor force appears to be inefficiently utilized probably due to over-supply and underutilization. Also important to note, family and hired labor seems not to be perfect substitutes possibly due to the high supervision costs of hired labor compared to family labor.

Table A3.2. Results of the estimated Mincer annual earning function of adult individuals

	Log of real annual individual earnings (*lnyrearn*)		
Independent variables	1	2	**3***
Education/schooling years	0.027***	0.031***	0.049***
	(0.01)	(0.01)	(0.01)
Age of adult individuals	0.064***	0.065***	0.029***
	(0.01)	(0.01)	(0.01)
Age of adult individuals squared	-0.001***	-0.001***	-0.000***
	(0.00)	(0.00)	(0.00)
Sex of household members (1= male, 0 = Female)	0.749***	0.741***	0.539***
	(0.04)	(0.04)	(0.09)
Dummy variable for year 2001	-0.569***	-0.605***	-0.661***
	(0.04)	(0.04)	(0.05)
Dummy variable for year 2003	-0.118***	-0.114***	-0.155***
	(0.03)	(0.03)	(0.04)
Dummy variable for population density (1 =high, 0= otherwise)		-0.084**	
		(0.04)	
Dummy variable for market access (1=high, 0= otherwise)		0.069*	
		(0.04)	
Dummy variable for agricultural potential (1= high rainfall, 0 =otherwise)		-0.164***	
		(0.03)	
Constant	9.948***	10.029***	10.731***
	(0.11)	(0.11)	(0.22)
Individual Random-Effects	YES	YES	NO
Individual Fixed-Effects	NO	NO	YES
Number of observations	3616	3616	3616
Number of individuals	2012	2012	2012
Chi2 statistic	830.171	915.988	256.158
Prob > chi2	0.000	0.000	0.000
R2-within	0.141	0.140	0.162
R2-between	0.238	0.250	0.164
R2-overall	0.227	0.235	0.169
Panel-level standard deviation	0.375	0.362	0.860
Standard deviation of error term	0.867	0.866	0.867
Rho (Panel fraction of variance)	0.157	0.149	0.496

Note: (i) Bootstrap (399) replications) standard errors are in parentheses. * Significant at 10%; ** significant at 5%; *** significant at 1%. (ii) Human capital variable was computed based on results of estimated FE model **3*.**

Results in Table A3.2 (above), shows that each year of schooling is associated with a 2.7-3.1% increase in individual earnings in models (1 & 2) estimated with individual RE, compared to 4.9% in model 3* that is estimated with individual FE to control for unobserved heterogeneity. Our estimates for the standard private rates of return to education are defined by the coefficient on education variable.

A test of whether children variables are endogenous was conducted using a robustfied Durbin-Wu-Hausman (DWH) method (see Cameron and Trivedi (2010)). Results of the first-stage estimation of this endogeneity test are displayed in Table A3.4 (below), while test results of the second-stage estimation of this DWH are summarized in Table A3.3. They confirm that children variables are indeed endogenous to household consumption decisions.

Table A3.3. Second-stage results of the endogeneity test of children endowment, a manually performed Robust Durbin-Wu-Hausman (DWH) test method

	Log of expenditure per adult-equivalent (Ug.shs)			
	Unstandardized Children variables		Standardized Children variables	
	Number	Adult-equivalent	Number	% Adult-equivalent
Independent variables	1	2	3	4
Log number of children below 10 years of age	0.004			
	(0.13)			
Log adult-equivalent of children<10 years of age		-0.004		
		(0.16)		
Log number of children<10 years of age per adult-equivalent			0.099	
			(0.31)	
Log proportion (%) of children<10 years of age in adult-equivalent				0.100
				(0.44)
Sex of the household head (1 = Male, 0= female)	0.168*	0.170	0.159	0.162
	(0.10)	(0.11)	(0.10)	(0.11)
Predicted log of household size in adult-equivalent for members>=10 years	-0.379***	-0.378***	-0.361**	-0.366**
	(0.14)	(0.13)	(0.15)	(0.15)
Dummy variable for year 2001	0.012	0.013	0.008	0.012
	(0.07)	(0.07)	(0.07)	(0.07)
Dummy variable for year 2003	-0.113**	-0.113*	-0.115*	-0.113*
	(0.06)	(0.06)	(0.06)	(0.06)
Residual variable for endogeneity test	-0.291**	-0.356**	-0.732**	-1.129**
	(0.14)	(0.16)	(0.35)	(0.47)
Constant	3.770***	3.774***	3.727***	3.740***
	(0.25)	(0.25)	(0.28)	(0.28)
Pooled OLS model estimation	Yes	Yes	Yes	Yes
Number of observations	912	912	912	912
Number of households				
Wald chi2	60.941	59.228	32.783	36.280
Prob > chi2	0.000	0.000	0.000	0.000
R-squared	0.063	0.065	0.038	0.042
Adjusted R-squared	0.057	0.058	0.031	0.036
Root MSE	0.711	0.711	0.721	0.719

Note: (i) Bootstrap (399) replications) robust standard errors are in parentheses. * Significant at 10%; ** significant at 5%; *** significant at 1%.

Table A3.4. First-stage results of the endogeneity test of children endowment, a manually performed Robust Durbin-Wu-Hausman (DWH) method

	Unstandardized Children variables		Children variables per adult-equivalent	
	Number	Adult-equivalent	Number	% Adult-equivalent
Independent variables	1	2	3	4
Sex of the household head (1 = Male, 0= female)	0.133*	0.109*	0.030	0.017
	(0.08)	(0.06)	(0.03)	(0.02)
Predicted log of household size in adult-equivalent for members >=10 years	0.484***	0.392***	-0.030	-0.015
	(0.11)	(0.09)	(0.04)	(0.02)
Dummy variable for year 2001	-0.006	-0.083	0.021	-0.016
	(0.07)	(0.06)	(0.02)	(0.01)
Dummy variable for year 2003	0.037	-0.006	0.014	-0.003
	(0.05)	(0.04)	(0.01)	(0.01)
Dummy for high rainfall (1= bi and uni high, 0= otherwise)	-0.017	-0.010	-0.022*	-0.014*
	(0.03)	(0.03)	(0.01)	(0.01)
Age of household head (years)	-0.004	-0.004**	-0.001	-0.001*
	(0.00)	(0.00)	(0.00)	(0.00)
Age of household head squared (years)	-0.000***	-0.000***	-0.000***	-0.000***
	(0.00)	(0.00)	(0.00)	(0.00)
Age household head got married (years)	0.008***	0.006***	0.004***	0.002***
	(0.00)	(0.00)	(0.00)	(0.00)
Age of household head's spouse got married (years)	-0.010***	-0.007***	-0.002*	-0.001*
	(0.00)	(0.00)	(0.00)	(0.00)
Other inkind non-land assets/1000 (Ug.shs) brought by head and spouse at the start of household	-0.000	-0.000	-0.000	-0.000
	(0.00)	(0.00)	(0.00)	(0.00)
Land (acres) brought in by head and spouse at the start of household	-0.001	-0.000	-0.001	-0.000
	(0.00)	(0.00)	(0.00)	(0.00)
Proportion of households that can afford at least 2 meals a day in the LC1	0.135*	0.109*	0.052**	0.037**
	(0.08)	(0.06)	(0.02)	(0.02)
Constant	0.630***	0.479***	0.425***	0.294***
	(0.18)	(0.14)	(0.06)	(0.04)
Pooled OLS model estimation	Yes	Yes	Yes	Yes
Number of observations	912	912	912	912
Number of households				
Wald chi2	158.999	176.933	284.737	312.321
Prob > chi2	0.000	0.000	0.000	0.000
R-squared	0.147	0.132	0.246	0.243
Adjusted R-squared	0.136	0.120	0.236	0.233
Root MSE	0.560	0.453	0.172	0.117

Note: (i) Bootstrap (399) replications) robust standard errors are in parentheses. * Significant at 10%; ** significant at 5%; *** significant at 1%.

Below (Figure A3.1- A3.2) are the bivariate scatterplots between several variables employed in the first-stage RC model estimation of the number and adult-equivalent children of rural households.

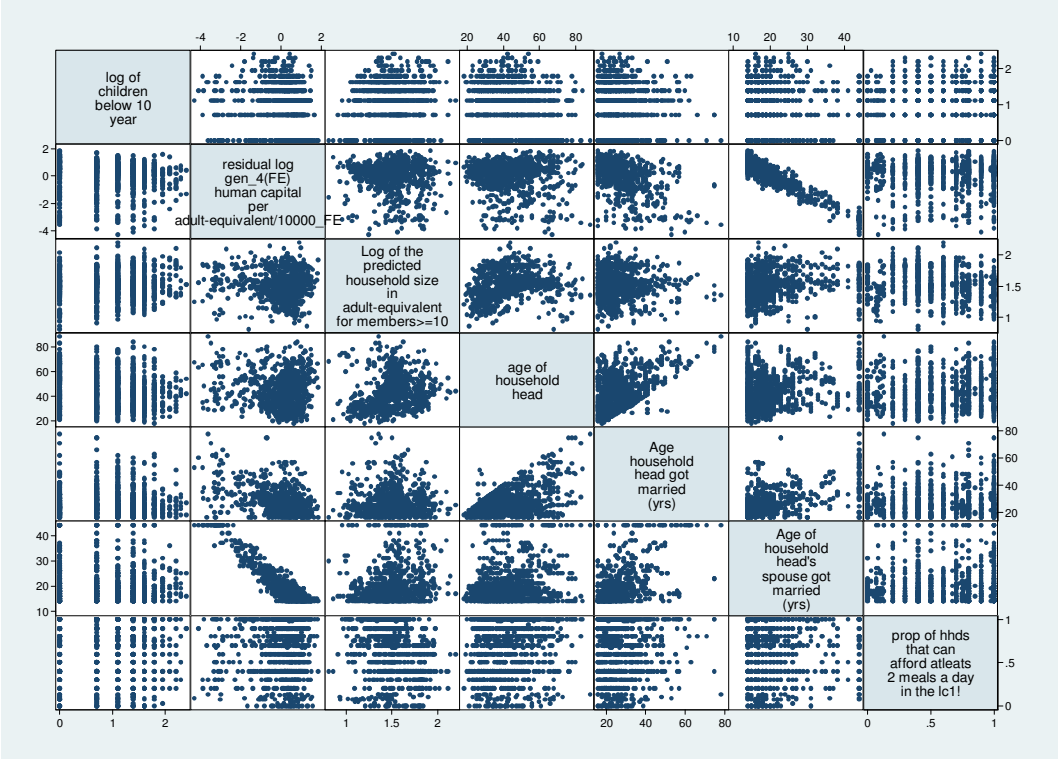
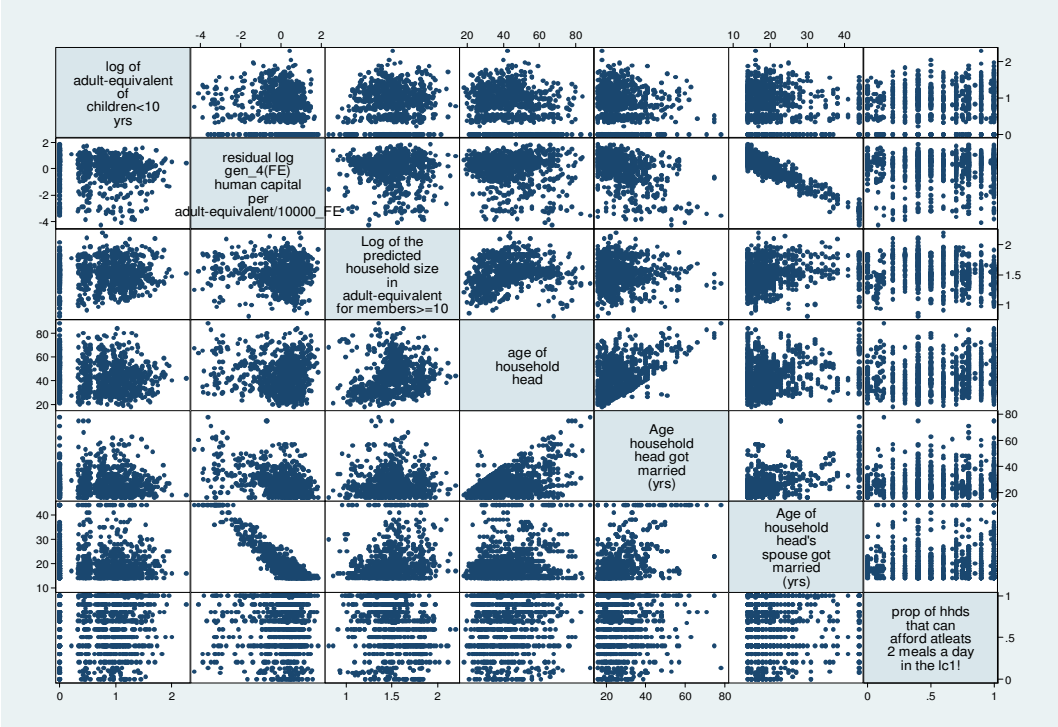


Figure A3.1. Correlation graph matrix for the variables in the first-stage RC estimation of number of children



FigureA3.2. Correlation graph matrix for the variables in the first-stage RC estimation of adult-equivalent of children

Below (Figure A3.3- A3.6) are the bivariate scatterplots between several variables employed in the second-stage RC model estimation of the absolute (and normalized) number and adult-equivalent children

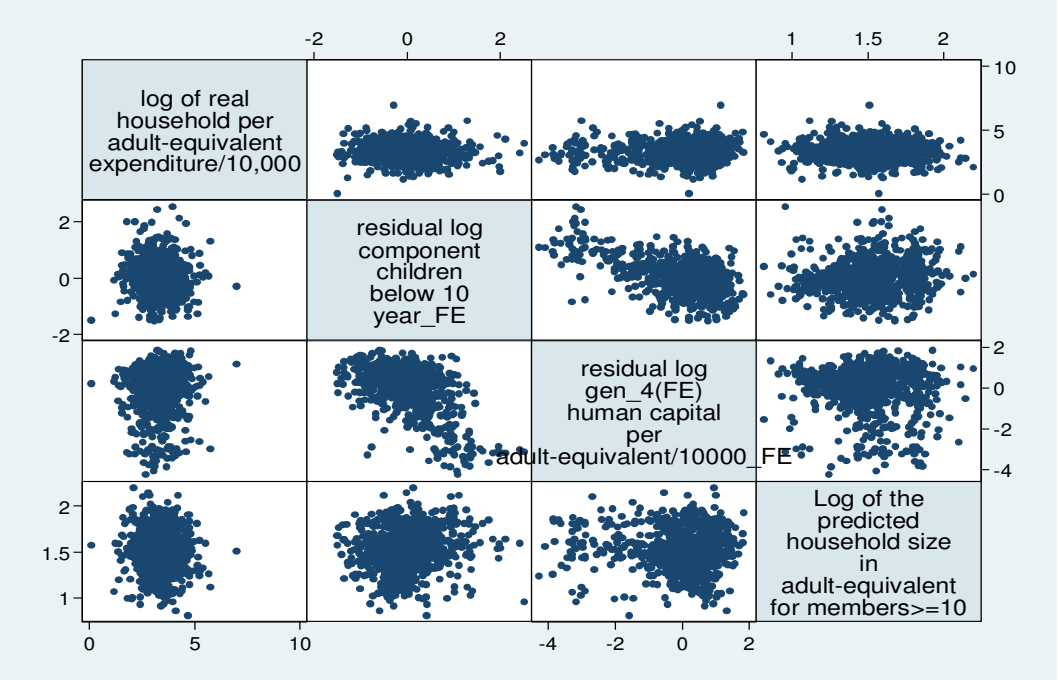


Figure A3.3. Correlation graph matrix of residual log component absolute number of children and human capital per adult-equivalent variables in the RC second-stage poverty (log expenditure) impact equation

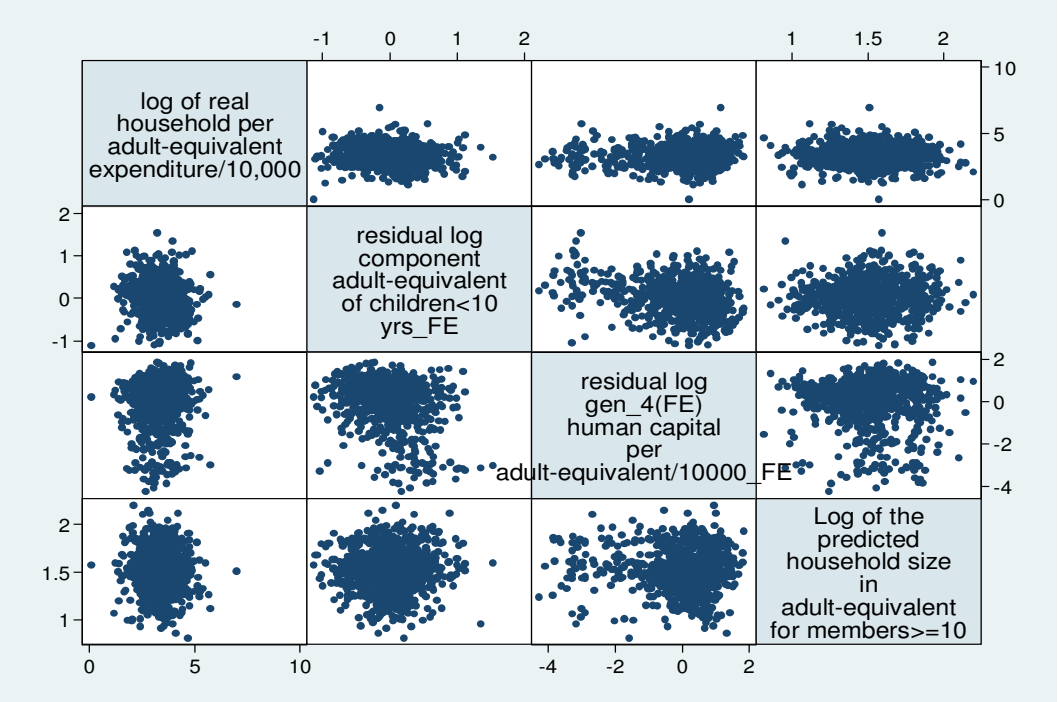


Figure A3.4. Correlation graph matrix of residual log component absolute adult-equivalent children and human capital per adult-equivalent variables in the RC second-stage poverty (log expenditure) impact equation

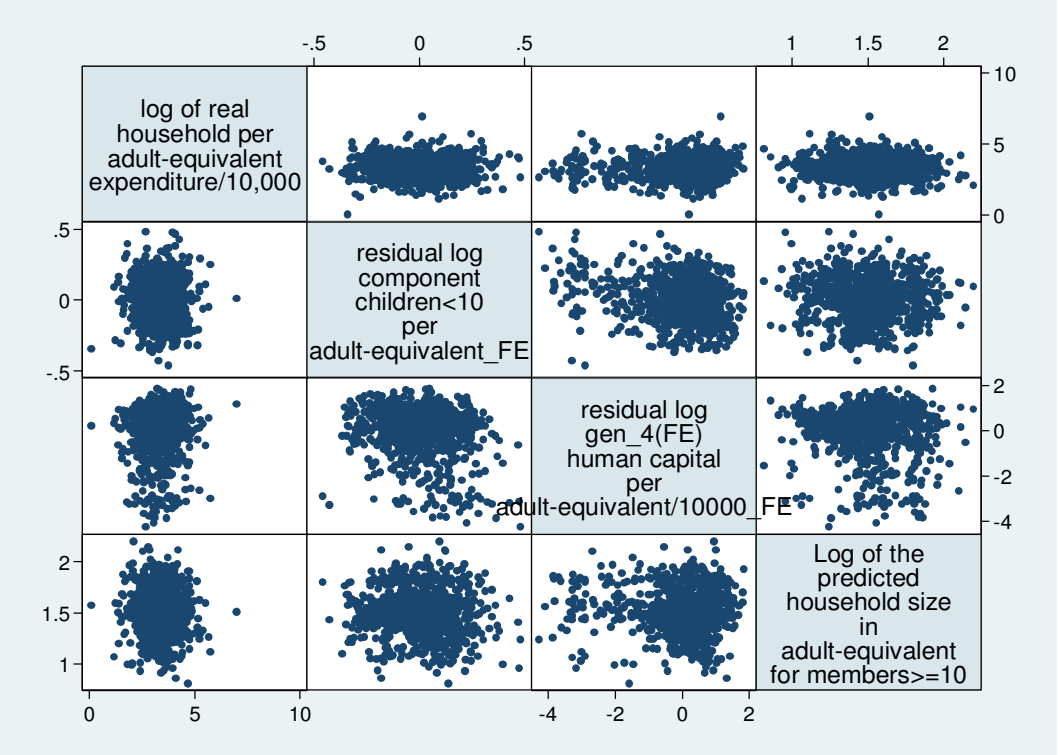


Figure A3.5. Correlation graph matrix of residual log component normalized number of children to adult-equivalent and human capital per adult-equivalent variables in the RC second-stage poverty (log expenditure) impact equation

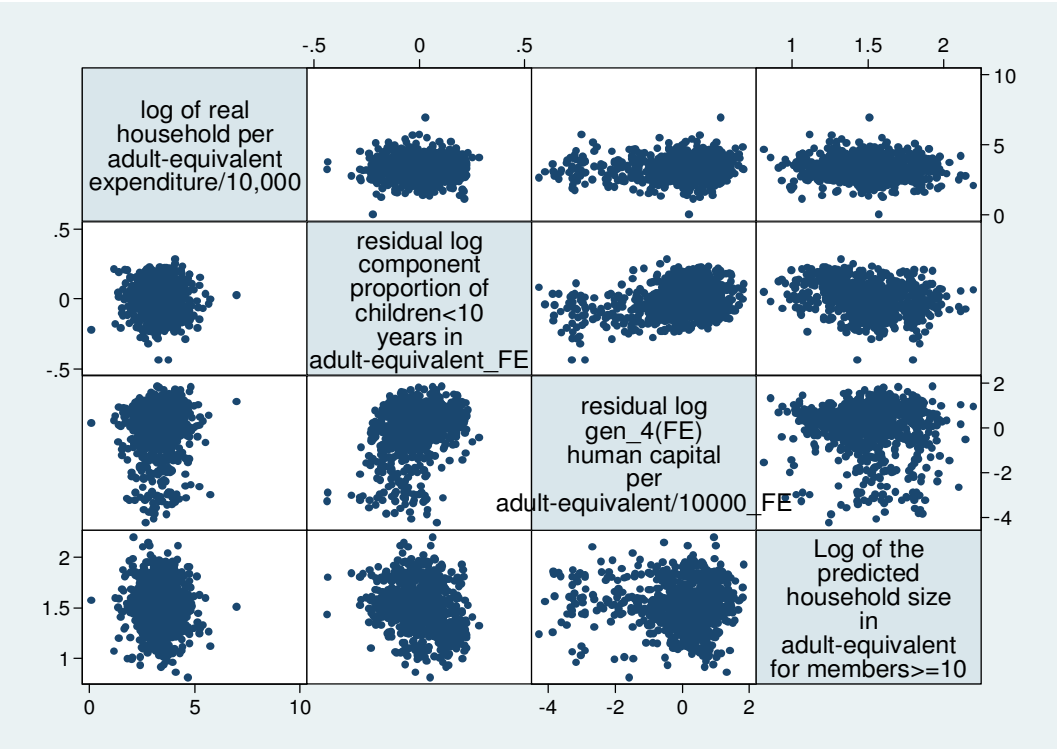


Figure A3.6. Correlation graph matrix of residual log component proportion (normalized to adult-equivalent) of children adult-equivalent and human capital per adult-equivalent variables in the RC second-stage poverty (log expenditure) impact equation

Several diagnostic regression tests (Figures A3.7-A3.12) in form of scatter plots, nonparametric lowess and local linear regressions were conducted to verify whether there are nonlinearities between each of the log transformed actual (and residual) variables of children < 10 years of age and the log of household expenditure per adult-equivalent

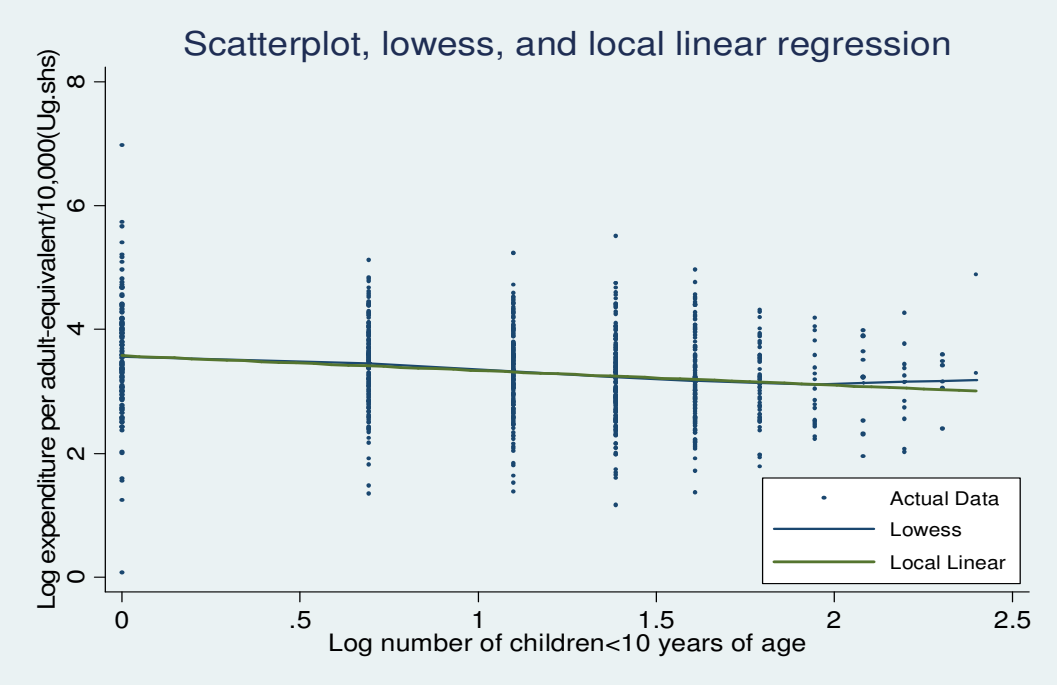


Figure A3.7. Scatterplot and nonparametric regression between the log number of children < 10 years of age and log of household expenditure per adult-equivalent

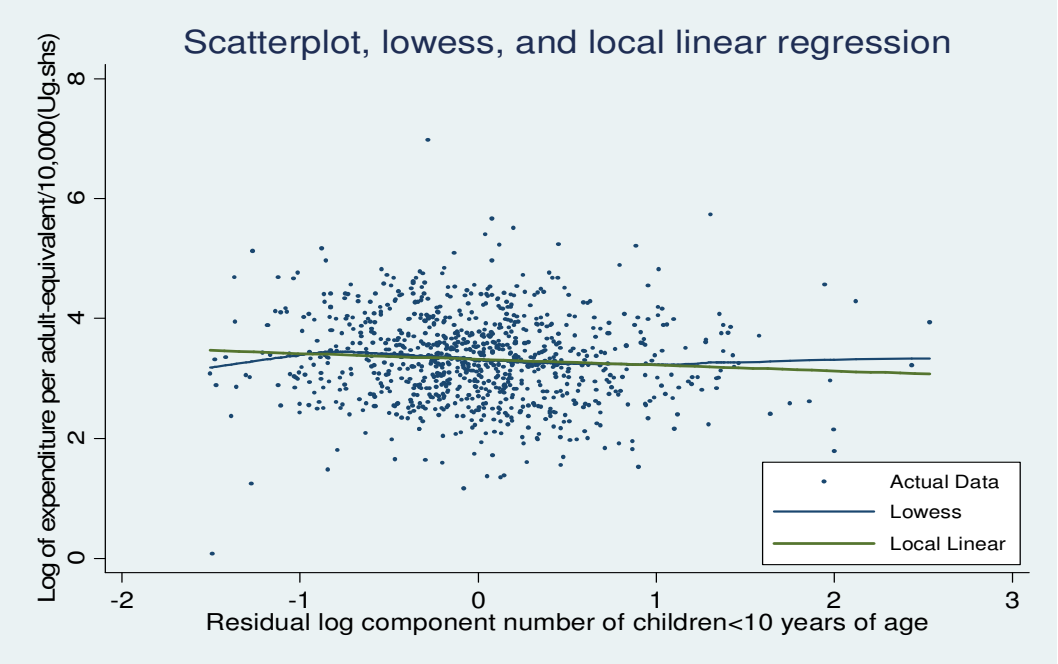


Figure A3.8. Scatterplot and nonparametric regression between the residual log component number of children < 10 years and log of household expenditure per adult-equivalent

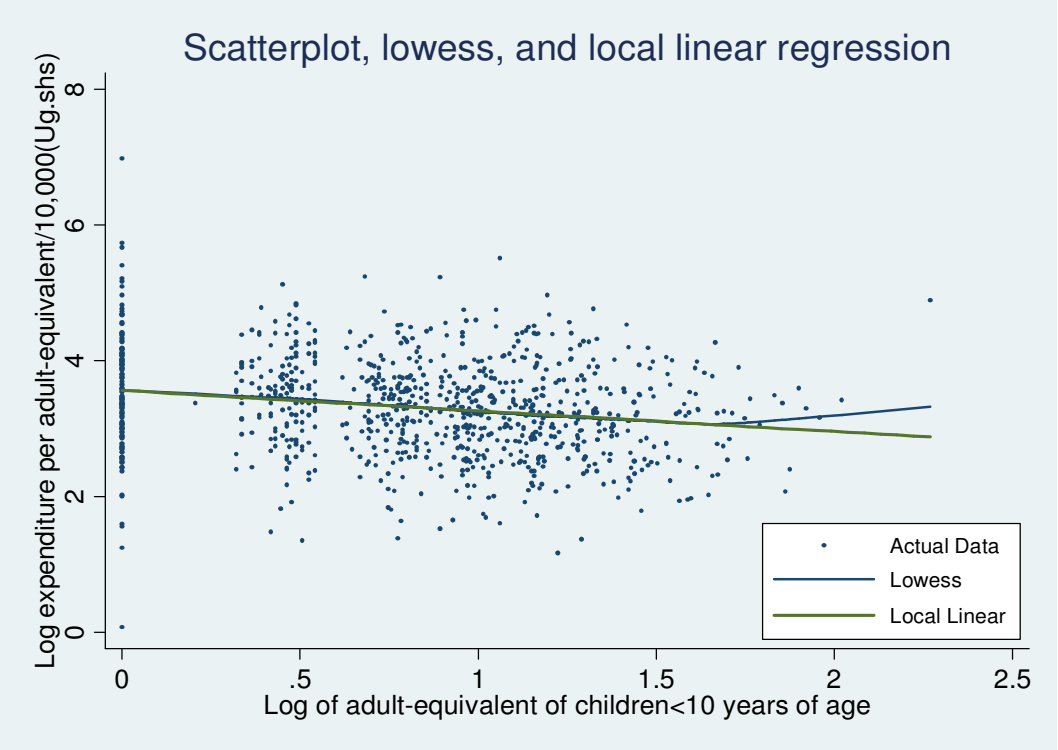


Figure A3.9. Scatterplot and nonparametric regression between the log of children adult-equivalent < 10 years and log of household expenditure per adult-equivalent

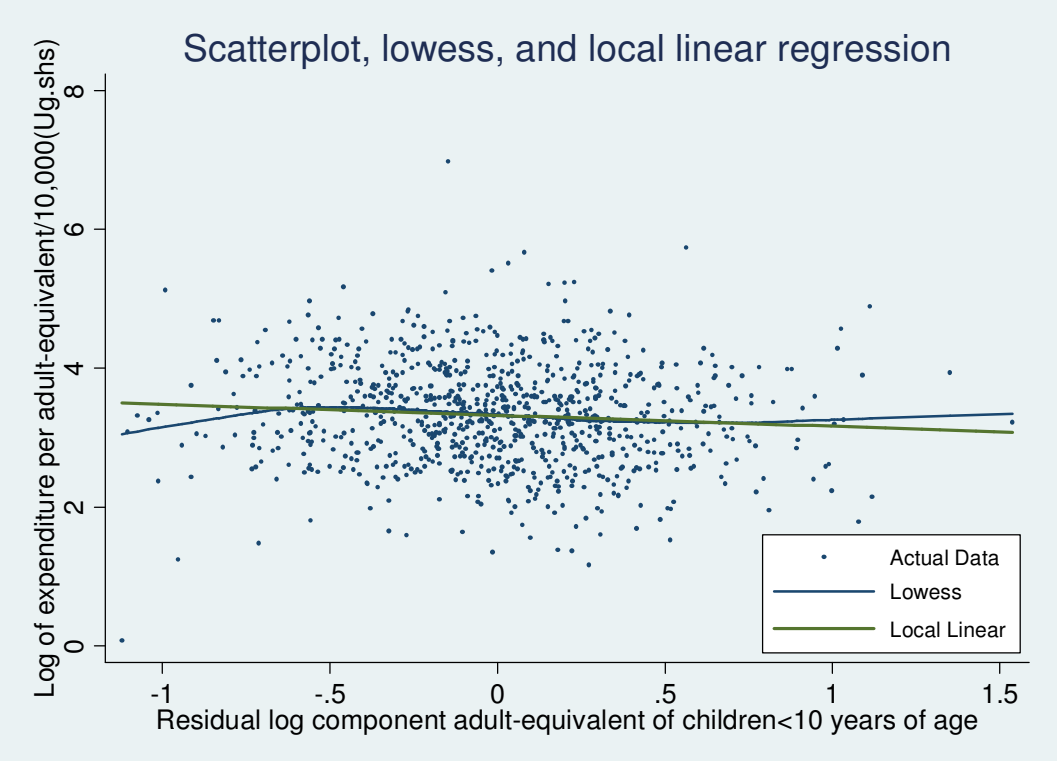


Figure A3.10. Scatterplot and nonparametric regression between the residual log component adult-equivalent children < 10 years and log of expenditure per adult-equivalent

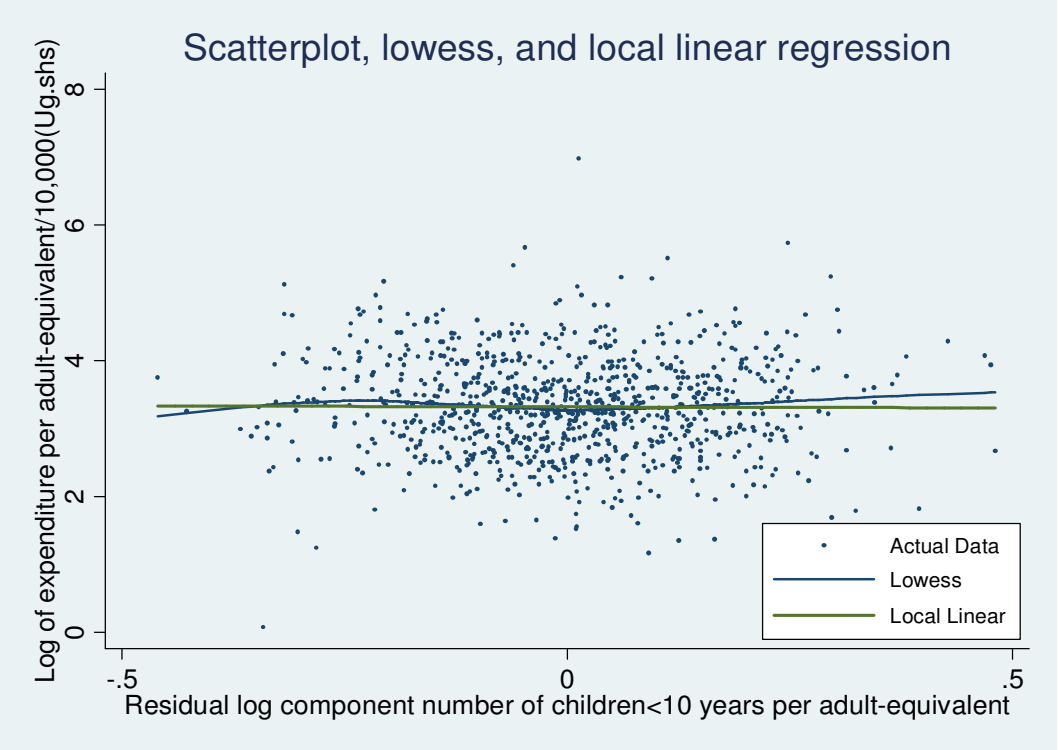


Figure A3.11. Scatterplot and nonparametric regression between the residual log component number of children < 10 years per adult-equivalent and log of household expenditure per adult-equivalent.

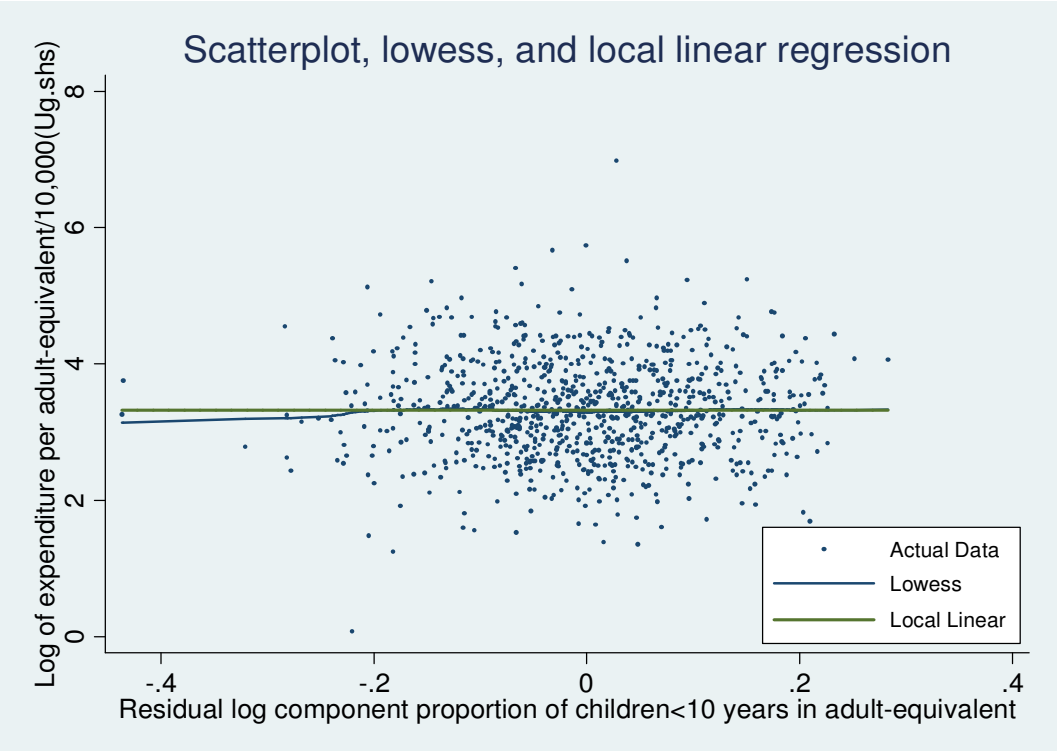


Figure A3.12. Scatterplot & nonparametric regression between the residual log component proportion (%) of children < 10 years (in adult-equivalents) and log of expenditure per adult-equivalent

Table A3.5. Correlation matrix of variables in the RC first-stage model for the number and adult-equivalent of children below 10 years

Variable name		*lchild10*	*lhumcapa1_e*	*lhadulteq10_h*	*agehhd*	*agehhd2*	*agemrhd*	agemrsp	*pro2mls*
Log number of children<10 years	*lchild10*	1.0000							
Residual log human capital	*lhumcapa1_e*	-0.0550	1.0000						
Log household size in adult-equivalent>=10 years	*lhadulteq10_h*	0.0486	-0.0494	1.0000					
Age of household head	*agehhd*	-0.2330	-0.1092	0.2095	1.0000				
Age of household head squared	*agehhd2*	-0.3124	-0.0923	0.2409	0.7300	1.0000			
Age household head got married	*agemrhd*	-0.1068	-0.4572	-0.0180	0.4902	0.3854	1.0000		
Age, household head's spouse got married	agemrsp	-0.1415	-0.9323	0.1395	0.2089	0.1662	0.4658	1.0000	
Proportion that afford 2 meals a day in the LC1	*pro2mls*	0.0508	0.0418	-0.2003	0.1357	-0.0165	0.0229	-0.0590	1.0000

Variable name		*lchildeq10*	*lhumcapa1_e*	*lhadulteq10_h*	*agehhd*	*agehhd2*	*agemrhd*	*agemrsp*	*pro2mls*
Log adult-equivalent of children<10 years	*lchildeq10*	1.0000							
Residual log human capital	*lhumcapa1_e*	-0.0664	1.0000						
Log household size in adult-equivalent>=10 years	*lhadulteq10_h*	0.0227	-0.0494	1.0000					
Age of household head	*agehhd*	-0.2156	-0.1092	0.2095	1.0000				
Age of household head squared	*agehhd2*	-0.2959	-0.0923	0.2409	0.7300	1.0000			
Age household head got married	*agemrhd*	-0.1017	-0.4572	-0.0180	0.4902	0.3854	1.0000		
Age, household head's spouse got married	*agemrsp*	-0.1324	-0.9323	0.1395	0.2089	0.1662	0.4658	1.0000	
Proportion that afford 2 meals a day in the LC1	*pro2mls*	0.0801	0.0418	-0.2003	0.1357	-0.0165	0.0229	-0.0590	1.0000

Note: Dummy variables and predicted asset variable controls are excluded from the correlation matrix

Table A3.6. Correlation matrix of independent variables in the RC, second-stage poverty (expenditure) impact equations

Models with children variables not normalized to adult-equivalent

		lnzpaqexp	*lchild10_e*	*lhumcapa1_e*	*lhadulteq10_h*
Log household expenditure/10,000 per AE	*lnzpaqexp*	1.0000			
Residual log children<10 years of age	*lchild10_e*	-0.0775	1.0000		
Residual log human capital per adult-equivalent/10000	*lhumcapa1_e*	0.0801	-0.5679	1.0000	
Log household size in adult-equivalent>=10 years	*lhadulteq10_h*	*-0.0818*	*0.0871*	*-0.0494*	*1.0000*

		lnzpaqexp	*lchildeq10_e*	*lhumcapa1_e*	*lhadulteq10_h*
Log household expenditure/10,000 per AE	*lnzpaqexp*	1.0000			
Residual log adult-equivalent children<10 years	*lchildeq10_e*	-0.0850	1.0000		
Residual log human capital per adult-equivalent/10000	*lhumcapa1_e*	0.0801	-0.2669	1.0000	
Log household size in adult-equivalent>=10 years	*lhadulteq10_h*	-0.0818	-0.0088	-0.0494	1.0000

Models with normalized children variables to adult-equivalent

		lnzpaqexp	*lchild10pa_e*	*lhumcapa1_e*	*lhadulteq10_h*
Log household expenditure/10,000 per AE	*lnzpaqexp*	1.0000			
Residual log number children<10 per adult-equivalent	*lchild10pa_e*	-0.0060	1.0000		
Residual log human capital per adult-equivalent/10000	*lhumcapa1_e*	0.0801	-0.2166	1.0000	
Log household size in adult-equivalent>=10 years	*lhadulteq10_h*	-0.0818	-0.0937	-0.0494	1.0000

		lnzpaqexp	*lchildeq10pa_e*	*lhumcapa1_e*	*lhadulteq10_h*
Log household expenditure/10,000 per AE	*lnzpaqexp*	1.0000			
Residual log proportion of children<10 in adult-equivalent	*lchildeq10pa_e*	-0.0003	1.0000		
Residual log human capital per adult-equivalent/10000	*lhumcapa1_e*	0.0801	0.3265	1.0000	
Log household size in adult-equivalent>=10 years	*lhadulteq10_h*	-0.0818	-0.2535	-0.0494	1.0000

Note: Dummy variables and predicted asset variable controls are excluded from the correlation matrix

APPENDIX A4 (RELEVANT FOR PAPER 4 IN THE MAIN TEXT)

The variable of household size is considered to be endogenous to the household consumption decisions. Here (Table A4.1), the panel random-effects model is employed to predict household adult-equivalent that is then employed in the estimation of the poverty impact equation.

TABLE A4.1
ESTIMATION OF PREDICTED HOUSEHOLD SIZE, A HOUSEHOLD RANDOM-EFFECTS MODEL

Independent variables	Household size in terms of adult equivalent
Age of spouse of household head	0.299***
	(0.04)
Age of spouse of household head squared	-0.003***
	(0.00)
Proportion of households that can afford at least 2 meals a day	0.868**
	(0.38)
Members of the household that passed away (died) in a year	0.543*
	(0.28)
Gini coefficient by district of land owned per adult equivalent	-2.456**
	(1.24)
Dummy variable for year 2001	1.606***
	(0.35)
Dummy variable for year 2003	-0.249*
	(0.14)
Constant	0.485
	(0.93)
Household random effects	YES
Number of observations	912
Number of households	304
Chi2 statistic	100.893
Prob > chi2	0.000
R2-within	0.058
R2-between	0.180
R2-overall	0.115
Panel-level standard deviation (sigma_u)	1.436
Standard deviation of error term (sigma_e)	2.967
Panel fraction of variance (rho)	0.190

Note. Bootstrap (399) replications) standard errors are in parentheses. * Significant at 10%; ** significant at 5%; *** significant at 1%

A test of whether endowments of livestock and farm equipments are endogenous was conducted using a robustfied Durbin-Wu-Hausman (DWH) method (see Cameron and Trivedi (2010)). Results of the DWH first-stage estimation are displayed in Table A4.2 (below).

TABLE A4.2
FIRST-STAGE RESULTS OF THE ENDOGENEITY TEST FOR LIVESTOCK ASSET & FARM EQUIPMENTS, A MANUALLY PERFORMED ROBUSTFIED DURBIN-WU-HAUSMAN (DWH) TEST METHOD

	Per adult-equivalent TLUs, & asset value /10000 (Ug.shs)			
	TLUs	Livestock	Farm Equipment	Livestock & farm equipments
Independent variables	1	2	3	4
Age of household head (yrs)	0.001	0.048	0.030	0.077
	(0.00)	(0.09)	(0.02)	(0.10)
Age of household head squared (yrs)	0.000	0.001	-0.000	0.001
	(0.00)	(0.00)	(0.00)	(0.00)
Age of spouse of household head (yrs)	-0.010	-0.084	-0.022	-0.106
	(0.02)	(0.58)	(0.12)	(0.67)
Age squared of spouse of household head (yrs)	0.000	0.001	0.000	0.001
	(0.00)	(0.01)	(0.00)	(0.01)
Dummy for high population density (1 = high, 0 = otherwise)	-0.092***	-2.687**	-0.330*	-3.017**
	(0.03)	(1.31)	(0.20)	(1.27)
Dummy for high population density (1 = high, 0 = otherwise)	-0.113***	-2.971***	-0.292*	-3.262***
	(0.03)	(0.98)	(0.16)	(1.10)
Land brought in by head and spouse at the start of the household (acres)	0.002	0.116	-0.000	0.116
	(0.00)	(0.09)	(0.01)	(0.10)
Sex of the household head (1= Male, 0=Female)	-0.003	-0.318	1.007***	0.688
	(0.06)	(2.18)	(0.23)	(2.36)
Proportion of households that can afford at least 2 meals a day (%)	-0.040	-0.366	0.183	-0.183
	(0.07)	(2.70)	(0.56)	(2.95)
Predicted household size in adult-equivalent	0.025	-0.071	-0.064	-0.135
	(0.05)	(1.88)	(0.41)	(2.17)
Members of the household that died/passed away in a year (no)	0.001	0.755	0.164	0.920
	(0.05)	(1.78)	(0.33)	(2.00)
Value of livestock wasted (died/lost/stolen) per adult-equivalent/10000 (Ug.shs)	0.025***	1.263***	0.144	1.408***
	(0.01)	(0.40)	(0.12)	(0.49)
Dummy variable for year 2001	-0.045	-0.713	0.144	-0.569
	(0.09)	(3.23)	(0.70)	(3.69)
Dummy variable for year 2003	-0.019	-0.215	0.008	-0.207
	(0.03)	(1.27)	(0.28)	(1.46)
Constant	0.359***	10.395***	0.999	11.395***
	(0.11)	(3.86)	(0.68)	(4.27)
Pooled ordinary least square (OLS) estimation	Yes	Yes	Yes	Yes
Number of observations	912	912	912	912
Wald chi2	86.964	51.215	43.379	50.557
Prob > chi2	0.000	0.000	0.000	0.000
R-squared	0.123	0.123	0.057	0.128
Adjusted R-squared	0.109	0.110	0.042	0.115
Root MSE	0.349	14.288	2.714	15.365

Note. (i) Bootstrap (399) replications) robust standard errors are in parentheses. * Significant at 10%; ** significant at 5%; *** significant at 1%.

Results of the robustfied Durbin-Wu-Hausman (DWH) method in the second-stage are summarized in Table A4.3. All the variables (tlu, livestock value, farm equipments, and the combined value of livestock and farm equipments) were found to be endogenous to household consumption decisions, see the highly significant coefficients on each of the residual variables.

TABLE A4.3

SECOND-STAGE RESULTS OF THE ENDOGENEITY TEST FOR LIVESTOCK ASSET AND FARM EQUIPMENTS, A MANUALLY PERFORMED ROBUSTFIED DURBIN-WU-HAUSMAN (DWH) TEST METHOD

	Household expenditure per adult-equivalent/10000 (Ug.shs)			
	TLUs	Livestock	Farm Equipment	Livestock & farm equipments
Independent variables	1	2	3	4
Tropical livestock units (TLUs) per adult-equivalent	-24.996**			
	(12.39)			
Livestock asset value per adult-equivalent /10000 (Ug.shs)		-0.558*		
		(0.30)		
Value of productive farm equipments per adult-equivalent/10000 (Ug.shs)			-6.006	
			(4.67)	
Value of livestock & productive farm equipments per adult-equivalent/10,000 (Ug.shs)				-0.553**
				(0.27)
Sex of the household head (1= Male, 0=Female)	2.358	2.034	8.339	2.559
	(4.39)	(4.50)	(6.80)	(4.54)
Predicted household size in adult-equivalent	-2.648**	-2.674**	-2.728**	-2.680*
	(1.31)	(1.34)	(1.36)	(1.40)
Members of the household that died/passed away in a year	-0.251	-0.218	-0.012	-0.150
	(1.78)	(1.87)	(1.70)	(1.80)
Value of livestock wasted (died/lost/stolen) per adult-equivalent/10000 (Ug.shs)	0.751**	0.821*	0.974	0.896*
	(0.36)	(0.48)	(0.77)	(0.51)
Dummy variable for year 2001	0.043	-0.686	-1.383	-0.750
	(2.79)	(2.79)	(2.73)	(2.62)
Dummy variable for year 2003	-1.859	-1.399	-1.216	-1.400
	(4.09)	(4.33)	(4.43)	(4.18)
Residual variable 1 for endogeneity test	53.439***			
	(13.75)			
Residual variable 2 for endogeneity test		1.326***		
		(0.31)		
Residual variable 3 for endogeneity test			9.901**	
			(4.81)	
Residual variable 4 for endogeneity test				1.338***
				(0.28)
Constant	58.701***	57.822***	58.551***	58.307***
	(10.58)	(10.74)	(10.99)	(11.72)
Pooled ordinary least square (OLS) estimation	Yes	Yes	Yes	Yes
Number of observations	912	912	912	912
Wald chi2	58.305	56.198	75.994	66.293
Prob > chi2	0.000	0.000	0.000	0.000
R-squared	0.053	0.062	0.059	0.074
Adjusted R-squared	0.045	0.054	0.051	0.066
Root MSE	45.093	44.882	44.954	44.597

Note. (i) Bootstrap (399) replications) robust standard errors are in parentheses. * Significant at 10%; ** significant at 5%; *** significant at 1%.

Diagnostic regression tests (Figures A4.1-A4.8) in form of scatter plots, nonparametric lowess and local linear regressions were conducted to verify whether there are nonlinearities between each of the actual (and residual) variables of livestock and physical farm equipments and the household expenditure per adult-equivalent

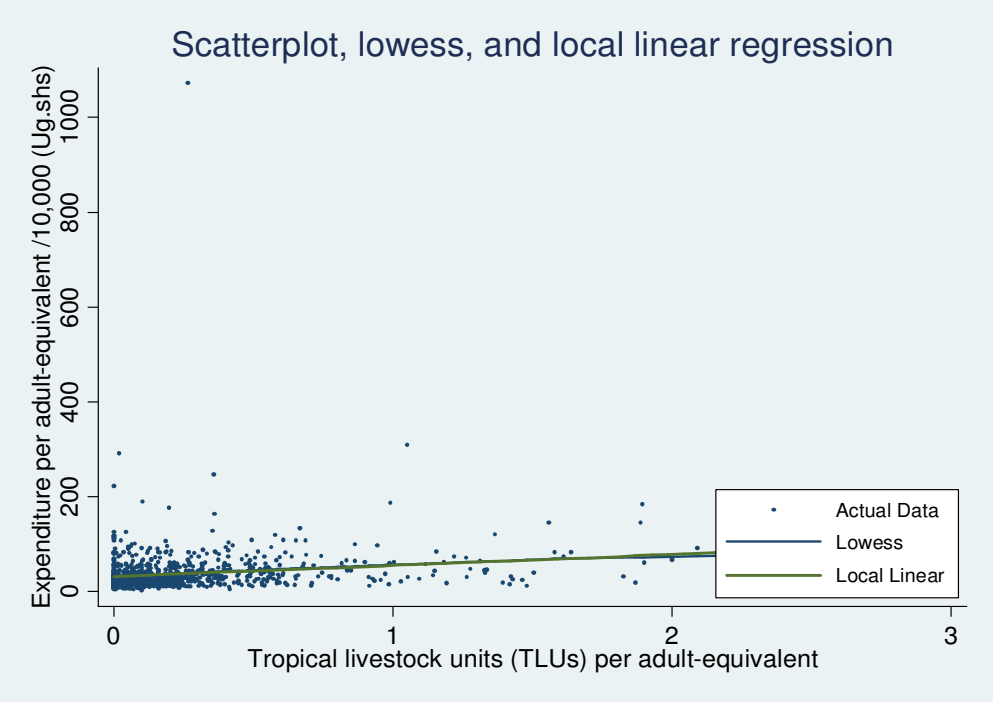


Figure A4.1. Scatterplot with lowess and local linear nonparametric regression between TLUs per adult-equivalent and household expenditure per adult-equivalent (Ug.shs)

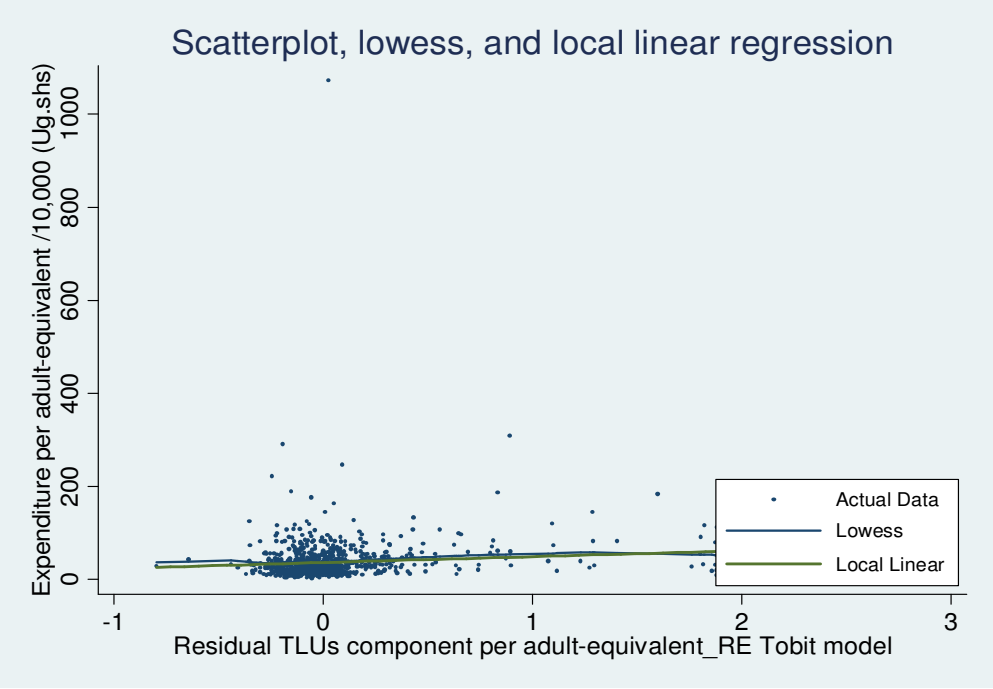


Figure A4.2. Scatterplot with lowess and local linear nonparametric regression between the residual TLUs per adult-equivalent and household expenditure per adult-equivalent (Ug.shs)

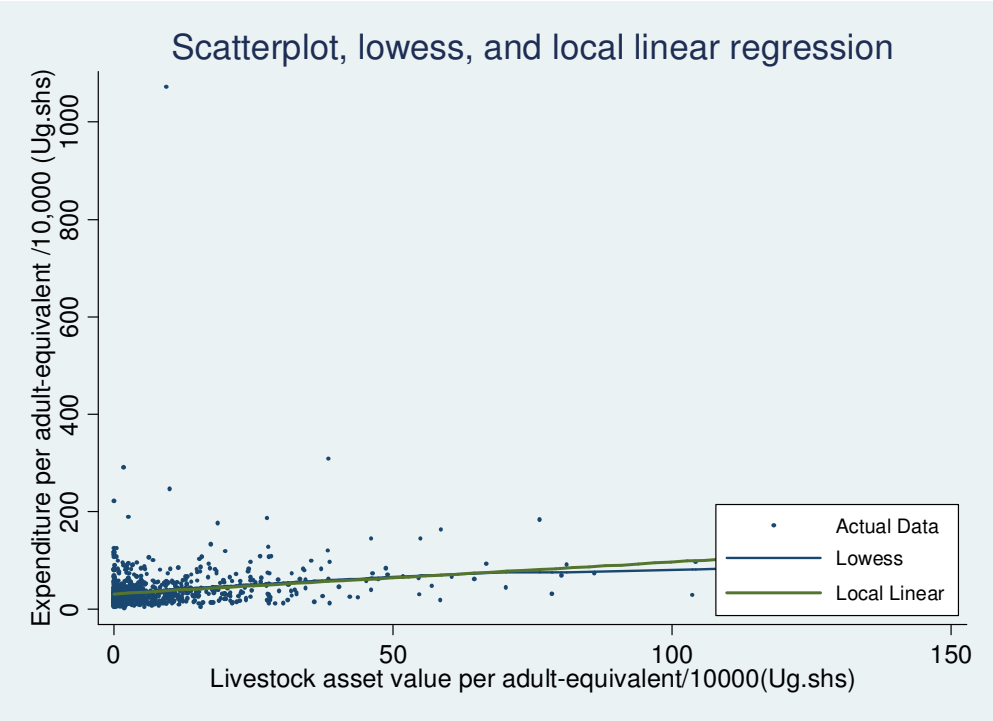


Figure A4.3. Scatterplot with lowess and local linear nonparametric regression between livestock value per adult-equivalent (ug.shs) and household expenditure per adult-equivalent (Ug.shs)

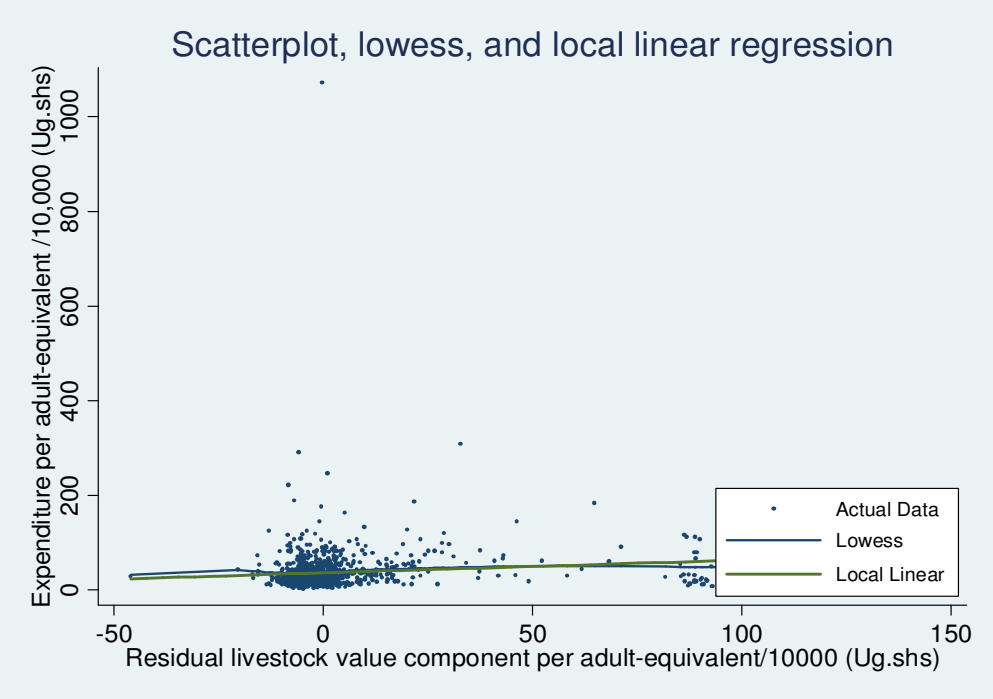


Figure A4.4. Scatterplot with lowess and local linear nonparametric regression between the residual livestock value per adult-equivalent and expenditure per adult-equivalent (Ug.shs)

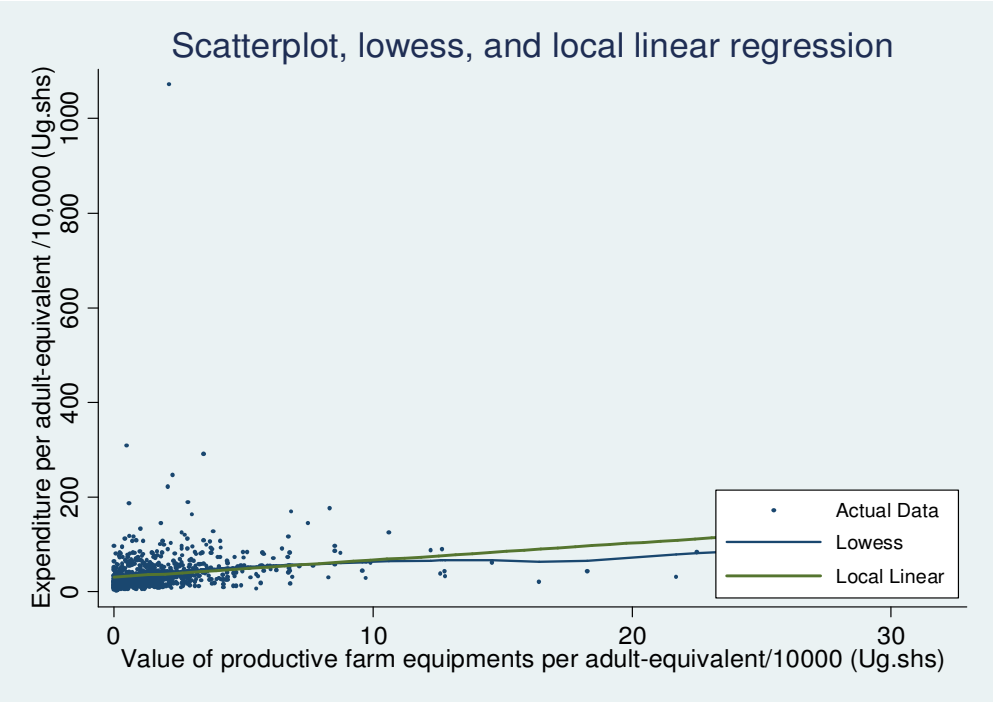


Figure A4.5. Scatterplot with lowess and local linear nonparametric regression between farm equipments per adult-equivalent (Ug.shs) and expenditure per adult-equivalent (Ug.shs)

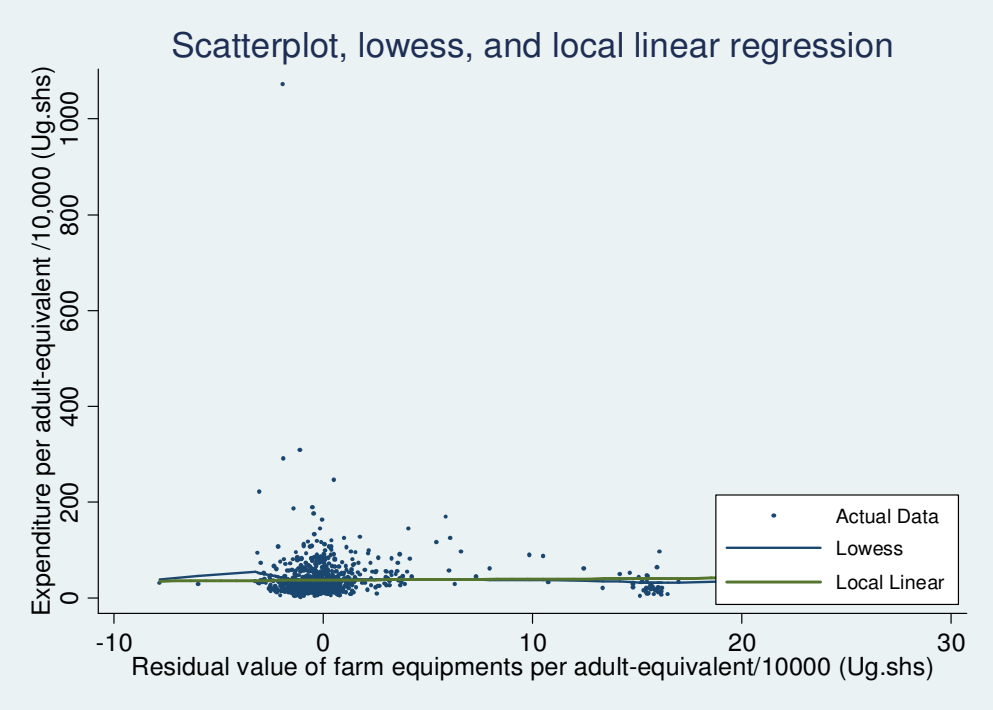


Figure A4.6. Scatterplot with lowess and local linear nonparametric regression between the residual farm equipment value per adult-equivalent and expenditure per adult-equivalent (Ug.shs)

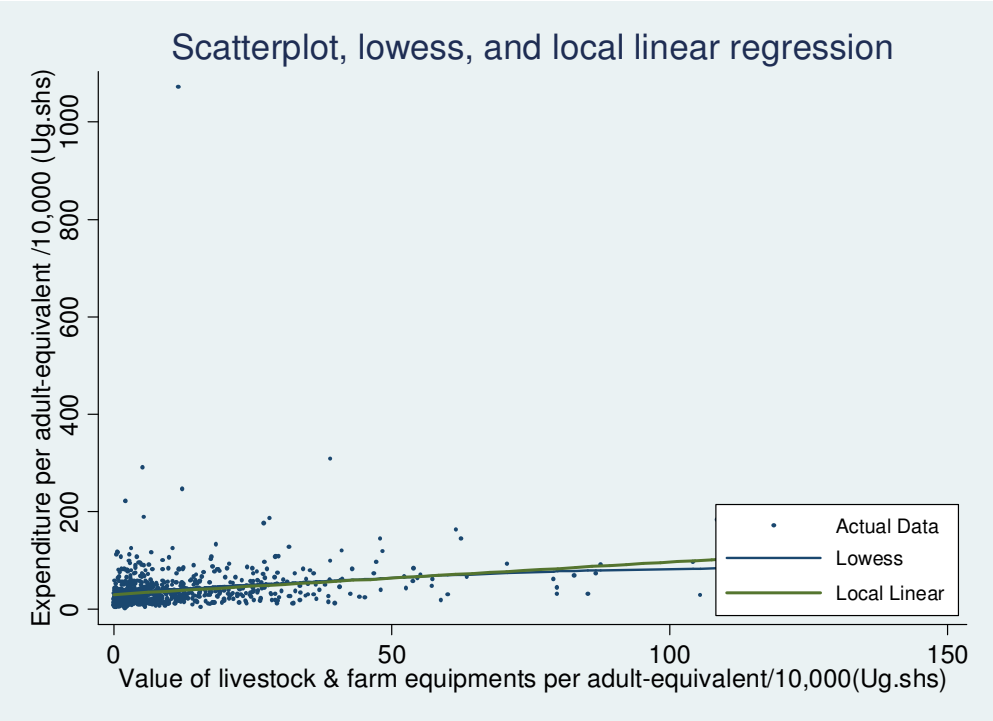


Figure A4.7. Scatterplot with lowess and local linear nonparametric regression between farm equipments per adult-equivalent (Ug.shs) and expenditure per adult-equivalent (Ug.shs)

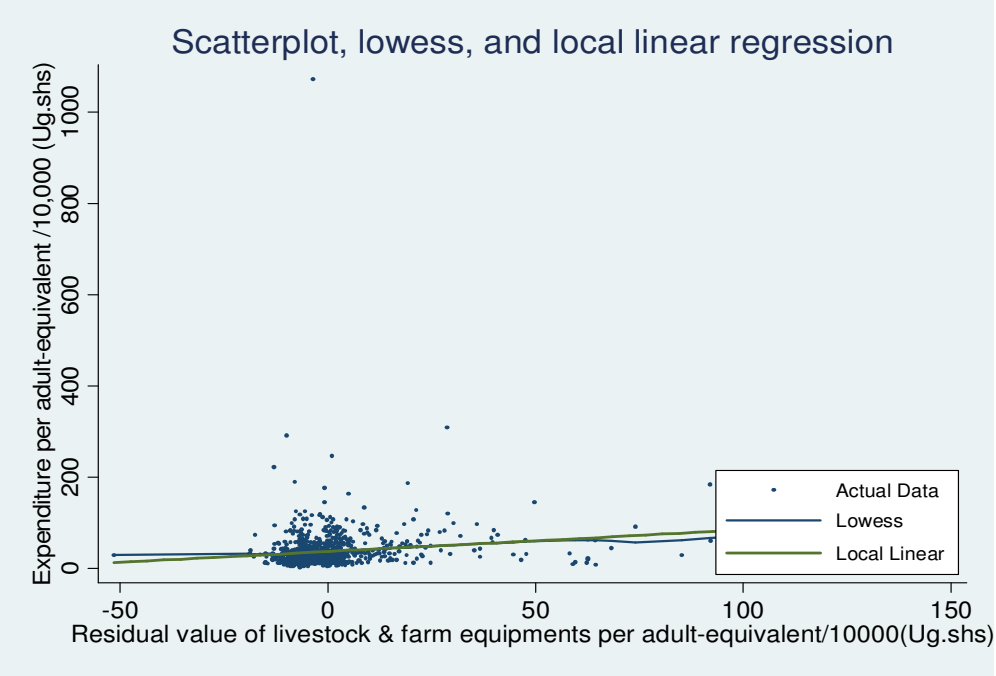


Figure A4.8. Scatterplot with lowess and local linear nonparametric regression between the residual value of livestock & farm equipment per adult-equivalent and household expenditure per adult-equivalent (Ug.shs)

APPENDIX A5 (RELEVANT FOR PAPER 5 IN THE MAIN TEXT)

Below (Figures A5.1-A5.2) are the bivariate scatterplots between several assets and other exogenous variables employed in the main first-differenced (FD) model with and without asset interactions

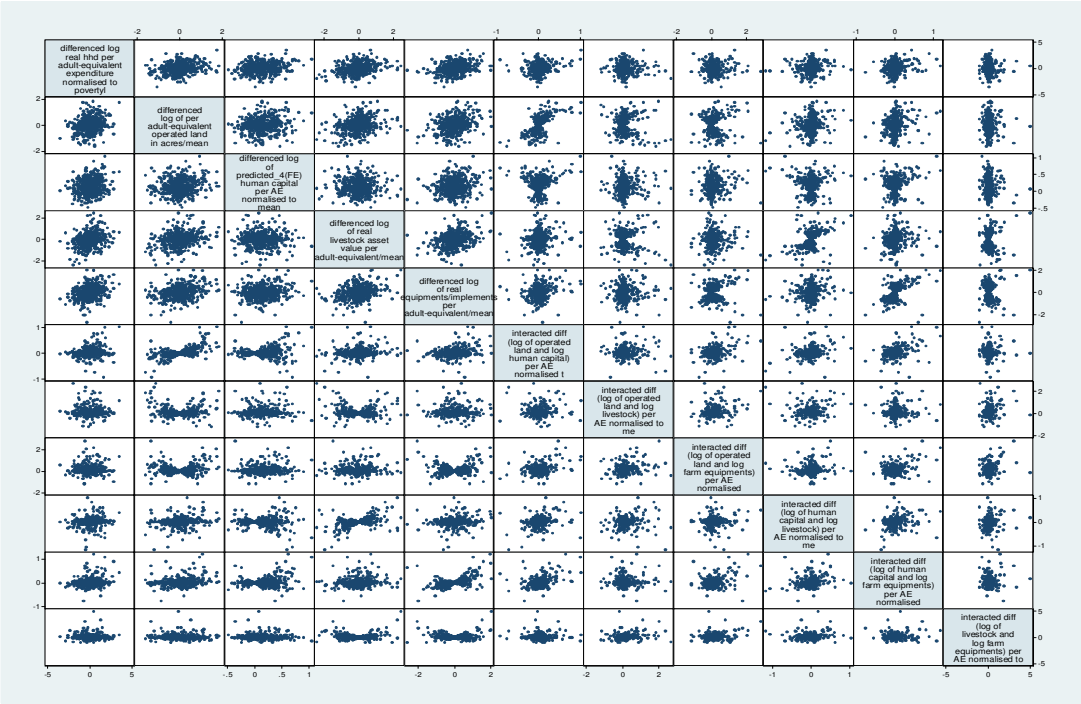


Figure A5.1. Correlation matrix (with interaction terms of productive assets) for the differenced household expenditure and explanatory variables in the main FD model of poverty impact equation

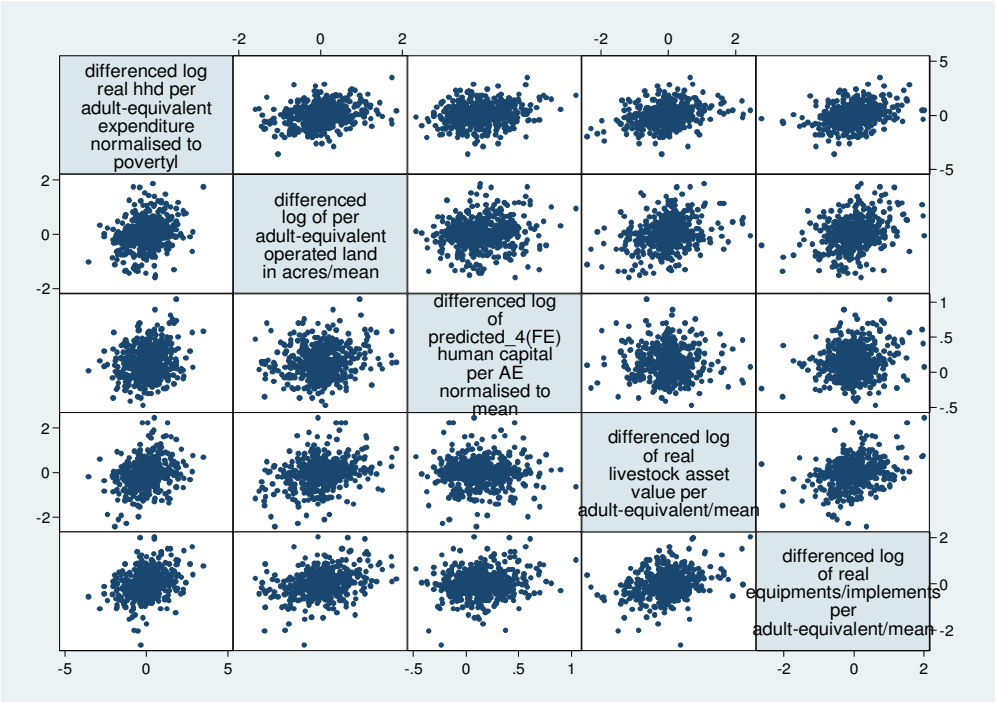


Figure A5.2. Correlation matrix (without interaction terms of productive assets) for the differenced household expenditure and explanatory variables in the main FD model of poverty impact equation

Diagnostic regression tests (Figures A5.3-A5.10) in form of scatter plots, nonparametric lowess and local linear regressions were conducted to verify whether there are nonlinearities between each of the normalized actual (and log transformed) asset variables and the normalized actual and log transformed household expenditure per adult-equivalent

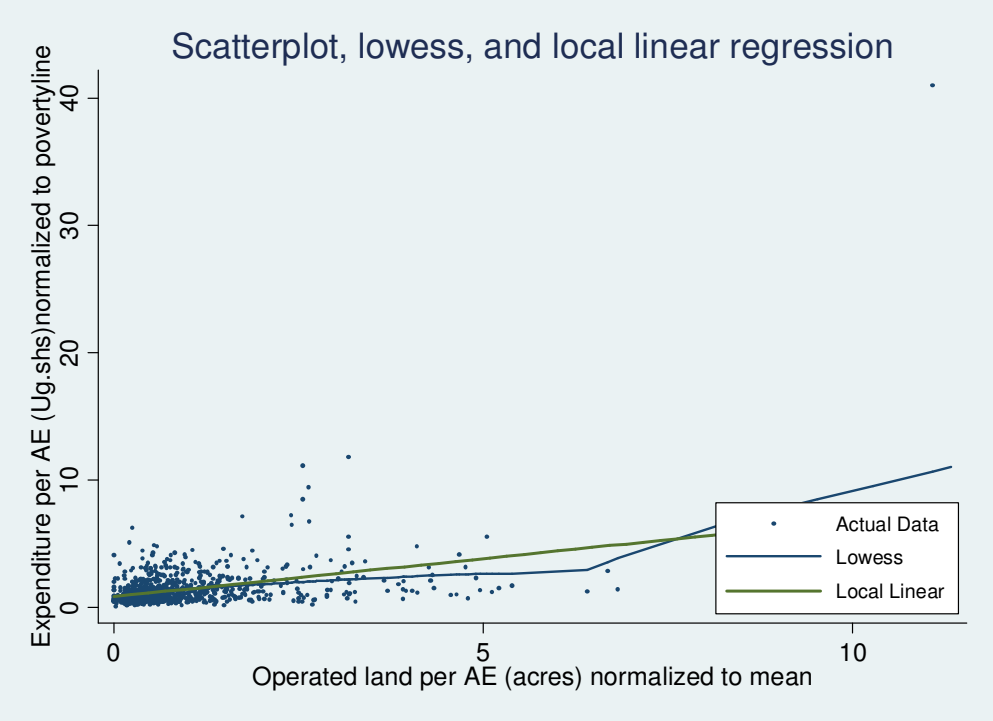


Figure A5.3. Scatterplot, lowess, and local linear nonparametric fits of normalized per adult-equivalent operated land to the sample mean, on the normalized household expenditure per adult-equivalent to poverty line

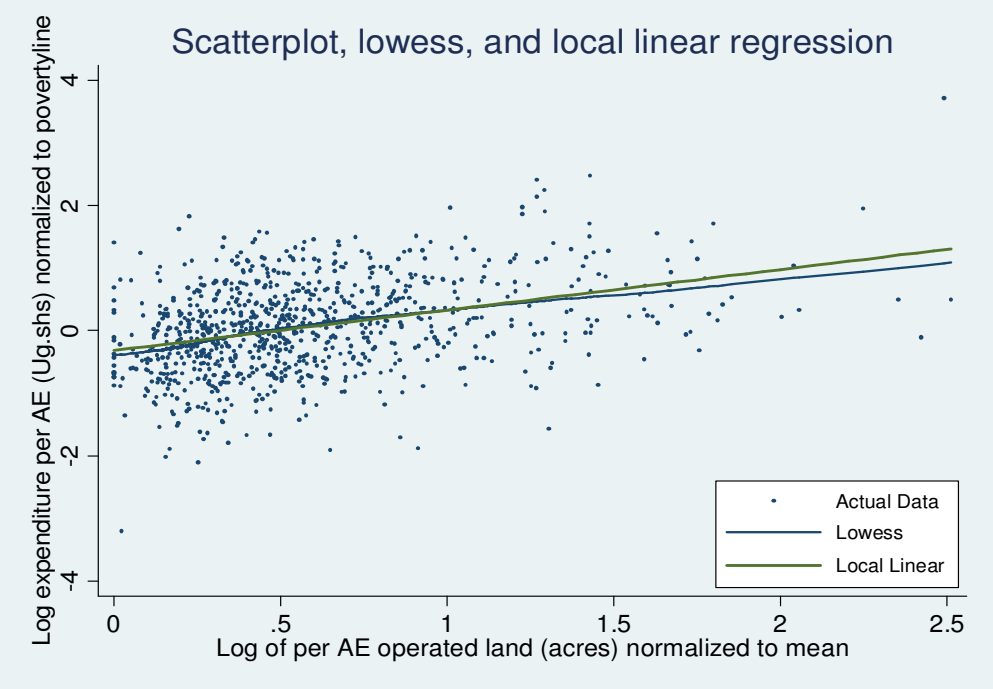


Figure A5.4. Scatterplot, lowess, and local linear nonparametric fits of log normalized per adult-equivalent operated land to sample mean on log normalized expenditure per adult-equivalent to poverty line

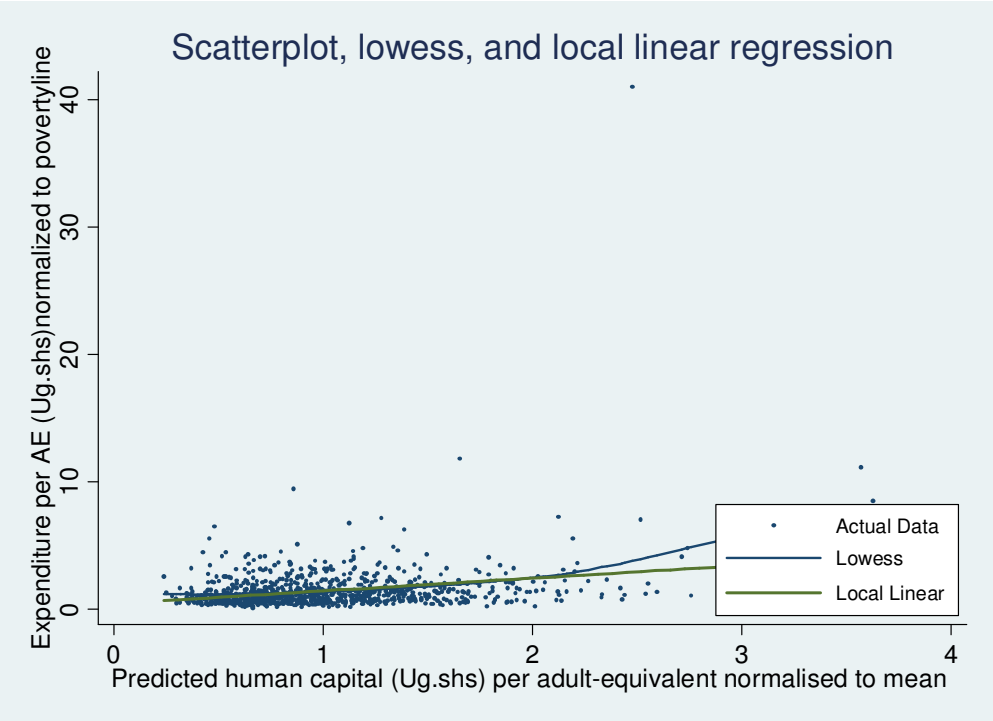


Figure A5.5. Scatterplot, lowess, and local linear nonparametric fits of normalized per adult-equivalent human capital to sample mean, on normalized household expenditure per adult-equivalent to poverty line

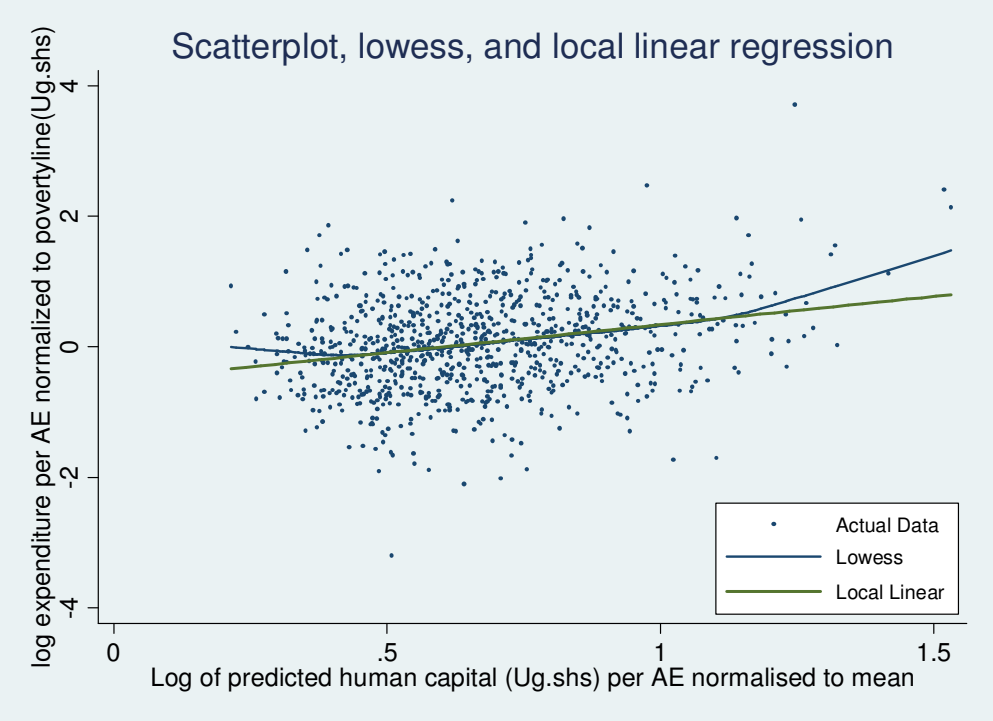


Figure A5.6. Scatterplot, lowess, and local linear nonparametric fits of log normalized per adult-equivalent human capital to sample mean, on log normalized household expenditure per adult-equivalent to poverty line

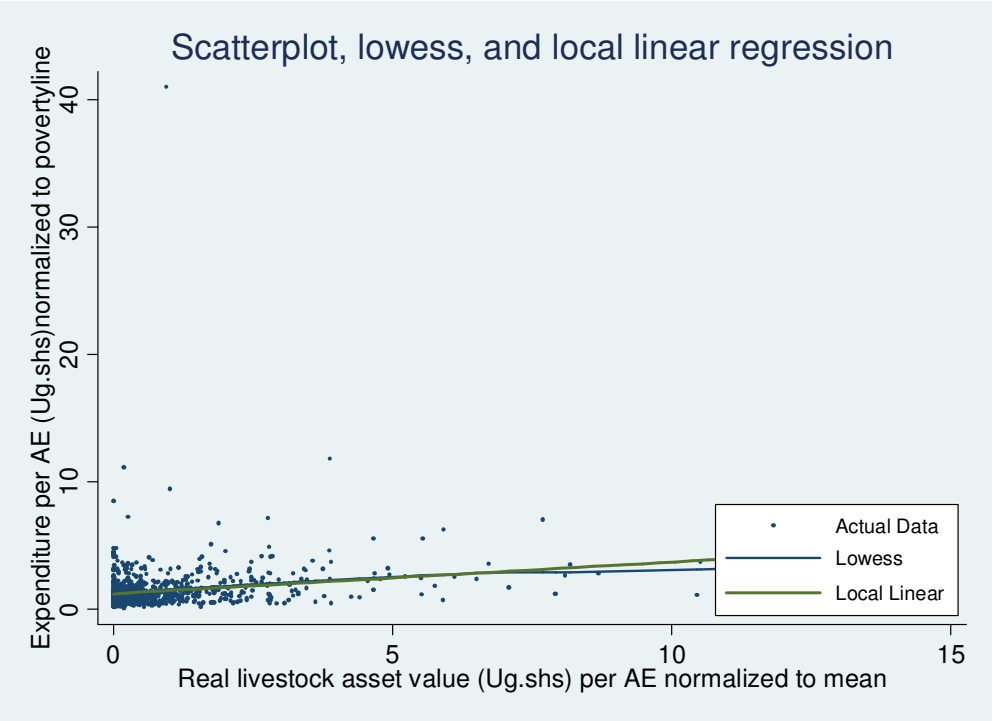


Figure A5.7. Scatterplot, lowess, and local linear nonparametric fits of normalized livestock per adult-equivalent to sample mean, on normalized household expenditure per adult-equivalent to poverty line

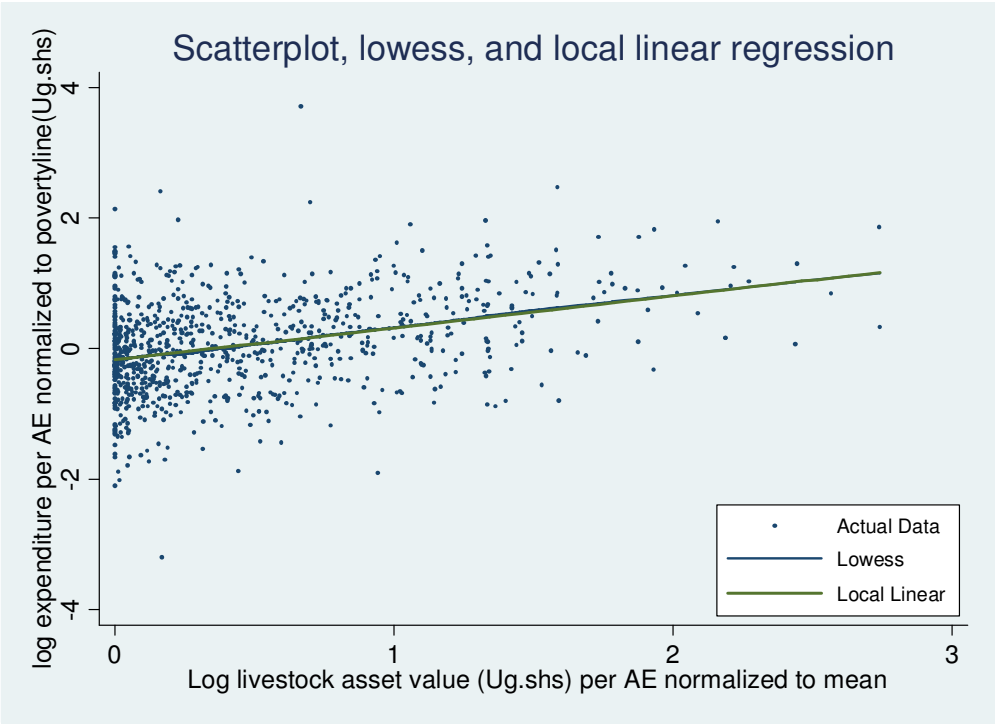


Figure A5.8. Scatterplot, lowess, and local linear nonparametric fits of log normalized livestock per adult-equivalent to sample mean, on log normalized household expenditure per adult-equivalent to poverty line

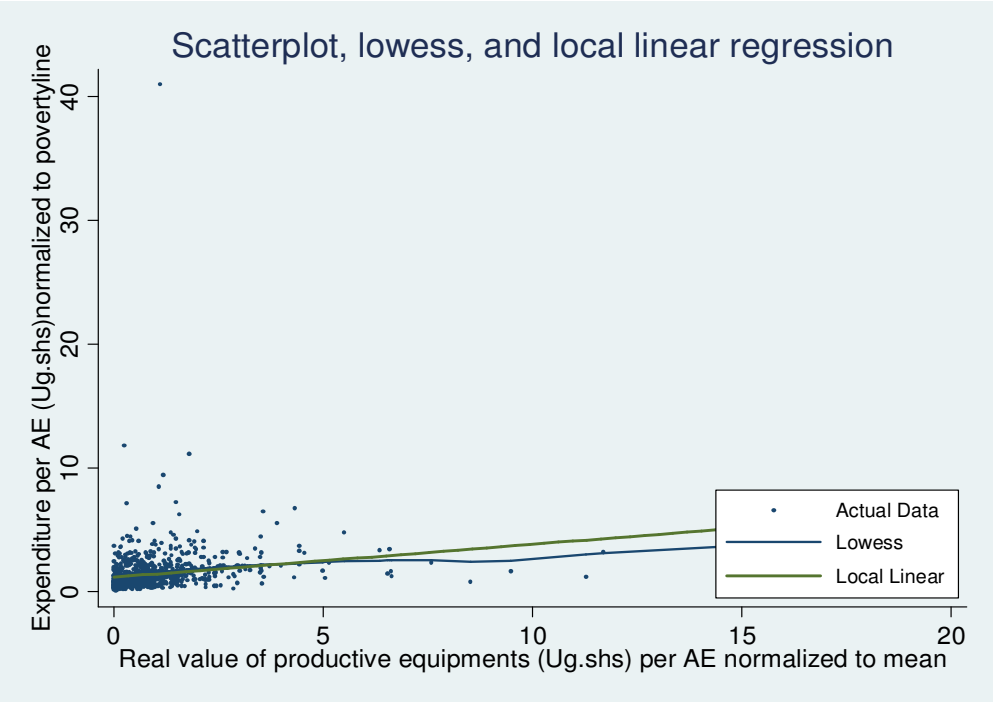


Figure A5.9. Scatterplot, lowess, and local linear nonparametric fits of normalized per adult-equivalent value of productive farm equipments to mean, on normalized expenditure per adult-equivalent to poverty line

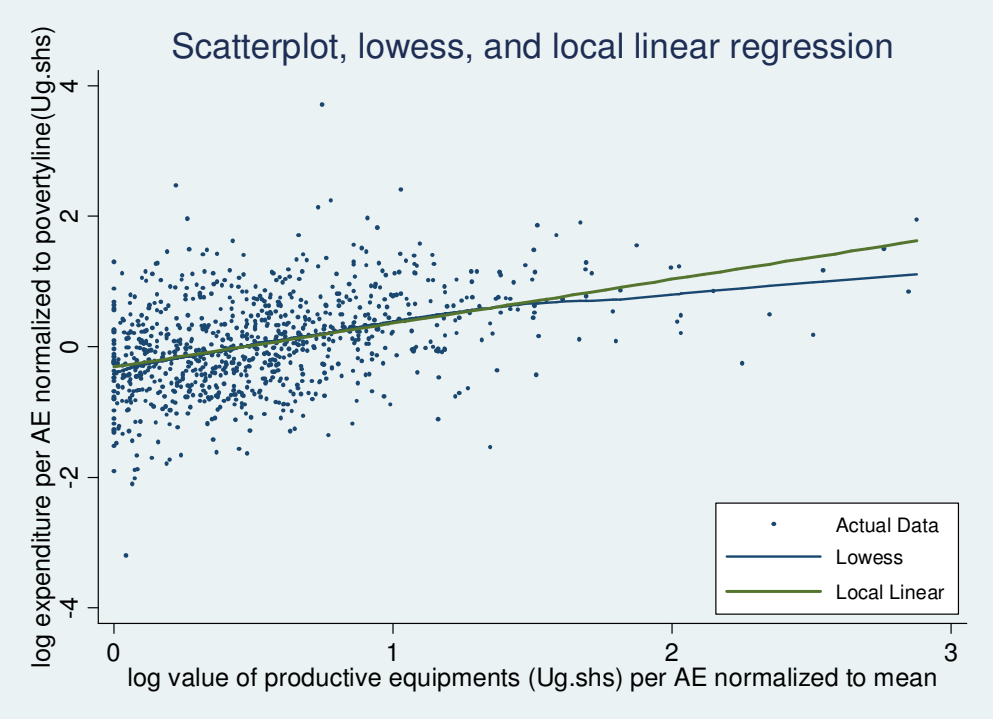


Figure A5.10. Scatterplot, lowess, and local linear nonparametric fits of log normalized per adult-equivalent value of productive equipments to mean, on log normalized expenditure per adult-equivalent to poverty line

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This thesis assesses the impact of access to productive assets on the welfare of rural farm households in Uganda. It consists of an introduction paper and five other independent papers. Paper I provides robust empirical evidence on the poverty reducing impact of land access through market and non-market avenues in rural Uganda. The paper found significant poverty reduction effects of increased land access in form of owned, operated and market accessed land after controlling for the endogeneity bias of land access and welfare effects of the unobserved heterogeneity.

Paper II employs the income approach to compute the value of household human capital. It then estimates the impact of changes in human capital endowment and health shocks to human capital on the real household expenditure per adult-equivalent. The paper found positive and highly significant poverty reducing effects of increased investment in human capital after controlling for the endogeneity bias of human capital variation, but the welfare effects of unexpected death and sickness shocks were insignificant.

Paper III estimates the impact of the endowment of young children on household expenditure per adult-equivalent. The analysis found small and insignificant impact of increased number and adult-equivalent of young children on household welfare after controlling for the endogeneity of children, differences in the number of children, and effects of adult human capital trade-offs. Limited short-term economic benefits of children and strong trade-off between adult human capital and young children in a household were found.

Paper IV assesses the impact of access to livestock holdings and productive farm equipments on expenditure per adult-equivalent. The analysis found significant welfare increasing effects of access to additional livestock holdings and productive farm equipments, after controlling for the endogeneity of each productive asset and unobserved heterogeneity. The study indicates high levels of inequality and strong positive correlation between each asset endowment and household expenditure.

Paper V provides a synthesis of the relative poverty reduction impacts of household access to four productive assets; land operated; human capital; livestock endowments; and physical farm equipments in rural Uganda. A translog production function based on first-differenced data and a semiparametric statistical smoothing method was applied to assess the returns to each asset and the likely asset interaction effects. An increase of each of four assets was found to generate strong and significant poverty reduction effects. Human capital and livestock, and livestock and farm equipment appeared to be potential substitutes in the household production process.

Professor Stein Holden and Professor Arild Angelsen were Tatwangire's main and co-supervisors.

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