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# Micro-Level Welfare Impacts of Agricultural Productivity: Evidence from Rural Malawi

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ABSTRACT *This article analyses the micro-level welfare impacts of agricultural productivity using a two-wave nationally representative, panel data from rural Malawi. Welfare is measured by various dimensions of poverty and food insecurity; and agricultural productivity is measured by maize yield and value of crop output per hectare. The poverty measures included per capita consumption expenditure, relative deprivation in terms of per capita consumption expenditure, poverty gap and severity of poverty; and the measures of food insecurity included caloric intake and relative deprivation in terms of caloric intake. Depending on the measure of welfare, the impact of agricultural productivity was estimated with a household fixed effects estimator, a two-part estimator or a correlated-random effect ordered probit estimator. The results indicate that growth in agricultural productivity has the expected welfare-improving effect. In terms of economic magnitude, however, both the direct effect and economy-wide spillover effect (in the non-farm sector) of a percentage increase in agricultural productivity on the poverty and food security measures are small. Efforts to effectively improve the welfare of rural agricultural households should therefore go beyond merely increasing agricultural (land) productivity.*

## 1. Introduction

> Most of the world's poor people earn their living from agriculture, so if we knew the economics of agriculture, we would know much of the economics of being poor. (Schultz, 1980, p. 639)

Despite the significant progress over the past three decades, poverty and food insecurity remain major developmental challenges in sub-Sahara Africa (SSA). Current estimates indicate that the region has the highest rates of poverty and undernourishment in the world – about 46.8 per cent of the population of SSA live on less than \$1.25 a day; 78 per cent live on less than \$2.50 a day; and about 23.2 per cent (220 million people in absolute terms) are undernourished (FAO, IFAD, & WFP, 2015; World Bank, 2011). Although the Millennium Development Goal (MDG) of halving extreme poverty by the end of 2015 has been achieved in the world as a whole, it is yet to be achieved in SSA where the extreme poverty rate has only been reduced by a quarter (FAO, IFAD, & WFP, 2015; World Bank, 2011). The MDG of reducing hunger by half and the World Food Summit (WFS) target of reducing the number of undernourished people by half are also yet to be achieved in SSA (FAO, IFAD, & WFP, 2015). Many development projects implemented by governments of SSA countries and their development partners have therefore prioritised poverty reduction and food insecurity, particularly in rural areas where the majority of the poor and food insecure are located.

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By virtue of the fact that the majority of the poor (75%) and food insecure in SSA live in rural areas and mainly depend either directly or indirectly on agriculture for livelihood, it is widely recognised that agriculture is a major channel through which poverty and food insecurity can be reduced in the sub-region (Ehui & Pender, 2005; IFAD, 2010). This notion is perhaps also based on the historical evidence that agriculture played an integral role in the marked success achieved in poverty reduction in Asia, and the evidence that growth in agriculture tends to be more beneficial to the poor than growth in other sectors of developing economies (DFID, 2004). There have therefore been major debates on the role that agriculture can potentially play in reducing poverty in SSA; but the empirical evidence backing such debates are limited.

With these considerations in mind, the present article informs the discussion by estimating the degree to which growth in agricultural productivity can affect the welfare of rural agricultural households using nationally representative panel data from Malawi. Specifically, the article examines the impact that increases in agricultural productivity can potentially have on the various dimensions – level, relative, depth and severity – of poverty and food insecurity of rural agricultural households. We focus on rural agricultural households because they represent the section of the SSA population that matter most for agriculture-led, welfare-improving initiatives.

This study adds to the development economics literature by providing a SSA, micro-level context to the existing literature on the welfare impacts of growth in agricultural productivity. Most of the empirical evidence on the subject are either at the macro-level (Breisinger, Diao, Thurlow, & Al Hassan, 2009; De Janvry & Sadoulet, 2010; Diao, Hazell, & Thurlow, 2010; Ravallion, 1990) or meso-level (Datt & Ravallion, 1998; Foster & Rosenzweig, 2004; Ravallion & Datt, 2002). To the best of our knowledge, Dzanku (2015) and Sarris, Savastano, and Christiaensen (2006) are the only studies that have addressed the micro-level welfare impacts of agricultural productivity in SSA. We improve upon and extend these studies in a number of ways. First, and perhaps most importantly, we extend the measures of household welfare beyond the '*incidence measures*' – measures (monetary or non-monetary) such as per capita consumption expenditure, whether or not a household is poor and so forth – used by Dzanku (2015) and Sarris et al. (2006). In addition to knowing the effect of agricultural productivity on the level of household welfare, it is important to also understand the extent to which growth in agricultural productivity affects household welfare relative to a pre-determined level of welfare (usually the poverty line) or the welfare of other households. Measuring poverty and food security in the relative, depth and severity dimensions provides such understanding.

Second, we conduct a simulation analysis to estimate how incremental changes in agricultural productivity affect poverty and ultra-poverty rates as well as the number of people that can potentially be lifted out of poverty and ultra-poverty. Third, the study controls for farm-wage income and income from off-farm economic activities. Because a significant proportion of rural agricultural households engage in off-farm income generating activities and most of them are net suppliers of labour in the agricultural labour market, failure to control for income from such activities in the welfare models of agricultural households could potentially result in omitted variable bias, thereby rendering the estimates inconsistent. Fourth, this study uses the approach developed by Oster (2015) and the control function approach to test and control for potential endogeneity of agricultural productivity in a household welfare equation due to omitted time-varying factors.

Lastly, this study uses a nationally representative panel data for the analyses. Although the data used by Dzanku (2015) is a panel of three years, it is not nationally representative – it covered eight villages in two (Eastern and Upper East) of the 10 regions of Ghana. Sarris et al. (2006) was based on cross-sectional data from two (Kilimanjaro and Ruvuma) of the 30 regions of Tanzania. The use of nationally representative, panel data in this paper allows us to: 1) control for unobserved (time variant and time-invariant) heterogeneity; 2) generalise the estimates for the whole of Malawi; and 3) use official national poverty lines.

Results from this study indicate that growth in agricultural productivity has the expected significantly positive effect on the welfare of rural agricultural households. However, both the *direct effects* and the economy-wide *spillover effect* (in the non-farm sector) of a percentage increase in agricultural productivity are small in terms of economic magnitude. The elasticity of per capita consumption expenditure with respect to maize yield and value of crop per hectare are 0.132 and 0.096 respectively; and the corresponding elasticity for per capita caloric intake are 0.06 and 0.054 respectively. The economy-wide *spillover effect* in the non-farm sector is estimated to be US$ 878,449.66 overall, and US$ 7.73 in per capita (of the rural agricultural population) terms. Efforts to effectively improve the welfare of rural agricultural households should go beyond the confines of merely increasing agricultural (land) productivity.

## 2. Background: agriculture, poverty and food insecurity in Malawi

Despite development in other sectors of the economy, like many other countries in SSA, agriculture continues to be the most important sector of Malawi's economy and an essential part of its social fabric. The sector accounts for approximately 30 per cent of gross domestic product (GDP), employs over 85 per cent of households, and serves as the main foreign exchange earner (60% for tobacco alone in 2014). With about 74 per cent of all rural income accounted for by crop production, agriculture is also the main source of livelihood for poor and rural households (Chirwa, Kumwenda, Jumbe, Chilonda, & Minde, 2008). The low share of agriculture in GDP relative to the large population and labour force employed in the sector proves that most people remain locked in low-productivity, subsistence agriculture. In other words, progress in transitioning smallholders from subsistence to commercial production, or out of agriculture altogether, has been limited.

Poverty in Malawi remains widespread. Estimates from the Third Integrated Household Survey (IHS3) indicate that 50.7 per cent of the population is poor and 24.5 per cent is ultra-poor; and the poverty and ultra-poverty gaps are 18.9 per cent and 7 per cent respectively. Using the international poverty lines based on purchasing power parities of $1.25 and $1.90 a day, the poverty rate for Malawi was 61.6 per cent and 70.9 per cent respectively in 2010 (World Bank, 2011). These figures classify Malawi, along with countries such as Burundi and Madagascar, among the poorest countries in SSA and the world as a whole. Malawi's headcount poverty barely dropped between 2004 and 2011, but countries such as Rwanda and Tanzania that had high poverty rates like Malawi in 2004 have recorded considerable reductions in poverty since then. In addition, countries such as Ghana, Ethiopia and Uganda had lower poverty rates than Malawi in 2004, but have also experienced declines in poverty rates since that time.

As in many other developing countries, poverty in Malawi is disproportionally a rural phenomenon. Between 2004/2005 and 2010/2011, although national poverty rates were high and decreased only slightly, poverty and ultra-poverty in urban areas fell significantly from 24.5 per cent to 17.3 per cent and from 7.5 per cent to 4.3 per cent respectively (World Bank, 2017). The poverty gap and severity of poverty in the urban areas also fell significantly from 7.1 to 4.8 percentage points and from 2.8 to 2.0 percentage points respectively between 2004 and 2011 (World Bank, 2017). In rural Malawi, however, poverty stagnated at about 56 per cent between 2004/2005 and 2010/2011, and the ultra-poverty rate increased significantly from 24.2 per cent to 28.1 per cent over the same period (World Bank, 2017). The poverty gap, severity of poverty and ultra-poverty also worsened in rural Malawi between 2004 and 2011.

Like poverty, food insecurity is prevalent and a rural phenomenon in Malawi. Nationally, the caloric intake of over 50 per cent of the population falls short of the minimum daily caloric requirement of 2100 calories per day between 2004 and 2013 (World Bank, 2017). In fact, the proportion of the undernourished population increased slightly from 50 per cent in 2004 to 51 per cent in 2013. Child malnutrition is also high in Malawi. Using the Demographic Health Survey (DHS), World Bank (2017) reports that the rate of stunting was 47.8 per cent in 2013, about a five percentage point decrease from the 2004 value. The percentage of underweight children dropped from 18.6 per cent to 14.1 per cent between 2004 and 2010 while the prevalence of wasting fell from 6.2 to 4.1 over the same period. Unsurprisingly, like poverty, undernourishment is disproportionally higher in rural areas than it is in the urban parts of the country. In 2013 for instance, undernourishment in rural Malawi was 53 per cent, about 11 percentage points higher than the corresponding value in urban areas (World Bank, 2017).

As in many agrarian developing countries, poverty reduction and improvement in other measures of welfare in Malawi have been identified to be closely linked to the performance of the agricultural sector. Chirwa and Muhome-Matita (2013) indicates that between 1990 and 2005, the agricultural sector grew by only 6.8 per cent per annum, and poverty fell by 0.2 per cent per annum. Because of this seemingly close relationship between the performance of the agricultural sector and poverty and the fact that poverty is predominantly rural and most of the rural households are farmers, most of the pro-poor development strategies in Malawi have focused on promoting growth in the agricultural sector. Notable among these development strategies is the large-scale Farm Input Subsidy Program (FISP) that the government is currently implementing. FISP has been the nation's main agricultural policy intervention in terms of government expenditure since its inception in the 2005/2006 agricultural year.

## 3. Conceptual framework

There are several pathways through which growth in agricultural productivity can potentially affect the welfare of agricultural households. First is through the *'food and income'* pathway. Increase in farm output per hectare can have the direct effect of increasing the availability of food and household income. De Janvry and Sadoulet (1996), Acharya and Sophal (2002) and Hazell, Ramasamy, and Aiyasamy (1991) provide evidence of the *'food and income'* pathway effect in Asia. De Janvry and Sadoulet (1996), for instance, observe that a percentage increase in total factor productivity would result in a 0.5 per cent increase in the income levels of smallholder farmers in Asia. Agriculture can also affect the welfare of households indirectly through the '*wage'* pathway. Agricultural expansion usually increases land under cultivation, intensity of cultivation and/or the frequency of cropping, which in turn increase the demand for hired farm labour (Hayami & Ruttan, 1985; Irz, Lin, Thirtle, & Wiggins, 2001; Lipton & Longhurst, 1989). The rising demand for hired farm labour drives up wages. Since hired farm labour is usually supplied by poor households, the increase in wages is likely to increase the income levels of poor households, and thus improve their welfare. Evidence of the 'wage' pathway is provided by Datt and Ravallion (1998) and Saxena and Farrington (2003). For instance, Saxena and Farrington (2003) reports that agricultural labour wages in India rose by 3 per cent per annum following increases in agricultural productivity between the 1970s and 1980s.

The *'food price'* pathway is yet another indirect channel through which improvement in agricultural productivity can affect the welfare of households. Increases in agricultural output supply can drive down food prices, and since most poor households in developing countries are net food buyers and spend a substantial part of their income on food, the reduced price of food will improve the poverty and food security status of households. A negative relationship between per capita food production and the price of staple foods has been observed in many SSA countries including Ghana, Ethiopia, Burkina Faso, Mali, and Sudan (Schneider & Gugerty, 2011); and in Asia (Biswanger and Quinzon, 1986; Otsuka, 2000). Improvement in agricultural productivity also indirectly affects the welfare of households through the '*non-farm sector'* pathway. Growth in agricultural productivity could provide raw material for the non-farm sector; and the increase in income that results from increases in agricultural productivity could increase the demand for goods and services produced in the non-farm sector. These will in turn stimulate employment in the non-farm sector through both forward and backward linkages and eventually increase off-farm income of households (Hanmer and Naschold, 2000; Mellor, 1999). The backward linkage involves farmers reinvesting the non-farm income in their agricultural activities. Results of several empirical evidence back the importance of the '*non-farm sector'* pathway (Delgado, Hopkins, & Kelly, 1998; Hazell & Hojjati, 1995; Bell, Hazell, & Slade, 1982; Timmer, 2003). Delgado et al. (1998), for instance, reports that a dollar increase in farm income results in a \$0.96 and \$1.88 increase in income elsewhere in the economies of Niger and Burkina Faso respectively.

Following Christiaensen and Demery (2006), in order to estimate the effect of agricultural productivity on the welfare of rural agricultural households, the indirect utility function of a rural agricultural households is defined as:

$$V(p,w,A) = \max_{q,L}[u(q,L)|\pi(p,w,,\ B) + wL = p.q] \quad (1)$$

where $U(q,L)$ is the utility of a rural agricultural household defined over the consumption of a vector of goods, $q$, and a vector of labour variables, $L$; $\pi(p,w,A,B)$ is the profit obtained from all (farm and off-farm) household enterprises, and depends on $p$ (a vector of prices for goods q), $w$ (vector of wage rates), $A$ (agricultural productivity) and $B$ (productivity of off-farm income-generating activities). The change in welfare resulting from a unit increase in agricultural productivity, $A$, is given by:

$$\alpha = \frac{dV}{\varphi dA} = [Q-q]\frac{dp}{dA} + \left[L - \left(L_f + L_{of}\right)\right]\frac{dw}{dA} + p\frac{dQ}{dA} \quad (2)$$

where $\varphi$ is the marginal utility of income; $[Q-q]$ is the difference between what the household produces and what it consumes; $L_f$ *and* $L_{of}$ are the optimal levels of farm and off-farm labour respectively; $\frac{dp}{dA}$ is the change in (food) prices resulting from a unit increase in agricultural productivity; $\frac{dw}{dA}$ is the change in agricultural wage resulting from the change in agricultural productivity; and $p\frac{dQ}{dA}$ is the monetary value resulting from a change in output caused by the change in agricultural productivity.

In this study, we estimate $\alpha$. A breakdown of $\alpha$ into its individual components ($\frac{dQ}{dA}$, $\frac{dp}{dA}$ *and* $\frac{dw}{dA}$ in Equation (2)) is beyond the scope of this study. Because Equation (2) does not capture the effect of agricultural productivity on welfare that come by way of the '*non-farm sector'* pathway, we call $\alpha$ the *direct effect*. In order to account for the effect that comes by way of the '*non-farm sector'*, we provide an estimate of the economy-wide *spillover effects* (independent of the estimation of the *direct effect*) of growth in agricultural productivity in the non-farm sector using the Benin, Thurlow, Diao, McCool, and Simtowe (2008) estimate of the multiplier between growth in the agricultural sector and the rest of the economy (1.11), the agricultural GDP of Malawi (US$ 962.16 million in constant 2010 prices), and the share of crop production in the agricultural GDP of Malawi (83%). The multiplier between the agricultural sector of Malawi and the rest of the economy of 1.11, means that a dollar increase in agricultural GDP results in an additional 0.11 dollar increase in the GDP of the non-agricultural sector (Benin et al., 2008).

## 4. Estimation strategy

In order to estimate the extent to which agricultural productivity affects the welfare of rural agricultural households, the empirical model is specified as:

$$W_{it} = \alpha A_{it} + \boldsymbol{X}_{it}\,\beta + \boldsymbol{H}_{it}\gamma + \boldsymbol{P}_{it}\delta + \boldsymbol{G}_{it}\tau + \varepsilon_{ij} \quad (3a)$$

$$\varepsilon_{ij} = c_i + \mu_{it} \quad (3b)$$

where $i$ and $t$ indexes household and year respectively; $W$ represents our various measures of household welfare; $A$ is household-level agricultural productivity; $X$ is a vector of variables measuring other sources of household income such as agricultural wage income, and non-farm income; $H$ is a vector of household characteristics, such as household size, landholding in hectares, and highest education achieved by a member of the household; $P$ is a vector of prices including commercial price of urea fertiliser, and a spatial food commodity price index; $G$ is a vector of household geo-variables such as distance to road, and agro-ecological zone; and $\varepsilon$ is the stochastic error term. The variables making up each of the vectors are defined in Table 1. $\alpha, \beta, \gamma, \delta,$ *and* $\tau$ are parameters, with $\alpha$ being the parameter of interest – the effect of agricultural productivity on household welfare. The error term, $\varepsilon_{ij}$, is made of two components – unobserved time-invariant factors $c_i$ (also called unobserved heterogeneity); and unobserved time-varying factors $\mu_{it}$, that affect the welfare of households. The

**Table 1.** Definition of variables in the welfare model

| Variables | Definition |
|---|---|
| Dependent Variables (measures of welfare) | |
| *Poverty measures* | |
| Per capita consumption expenditure | Expenditure on food, non-food, durables goods and housing per capita (‘000 MKW) |
| Relative deprivation in terms of consumption expenditure | Stark and Taylor’s (1989) index (‘000 MKW) |
| Poverty gap | Foster-Greer-Thorbecke (1984) index [0,1] |
| Severity of Poverty | Foster-Greer-Thorbecke (1984) index [0,1] |
| *Food security measures* | |
| Per capita caloric intake | Caloric intake from all sources of food (home-cooked and those purchased from outside) (‘000) |
| Relative deprivation in terms of caloric intake | Stark and Taylor’s (1989) index (‘000 MKW) |
| *Poverty and food security measure* | |
| Composite welfare | 1 = Poor and food insecure; 2 = Non-poor but food insecure or poor but food secured; 3 = Non-poor and food secured |
| Covariates | |
| *Agricultural Productivity* | |
| Value of crops per hectare | Value of annual crops per hectare (‘000 MKW per hectare) |
| Maize yield | Quantity of maize produced per hectare (‘000 Kg/ha) |
| *Other sources of income* | |
| Number of livestock | Number of livestock owned by the household |
| Net income from tree/permanent crop production | Net income from tree/permanent crop production (‘000 MKW) |
| Net income from non-farm enterprise | Net income from -farm enterprise (‘000 MKW) |
| Agricultural wage | Total agricultural wage earned (‘000 MKW) |
| Other sources of income | = 1 if household has other sources of income such as ag and non-ag wage, remittances etc |
| *Household characteristics* | |
| Household size | Number of people in the household |
| Dependency ratio (%) | Percentage of dependents in the household |
| Male-headed | = 1 if household is headed by a male |
| Age of HH head | Age of household head (years) |
| Age of household head squared | Squared of the age of household head |
| Education of the most educated HH member | Number of years of education of the most educated household member |
| Landholding (Ha) | Hectares of land that household has the right to cultivate |
| Owns crop storage house | = 1 if household owns a crop storage house |
| Accessed credit | = 1 if household had access to credit of any sort |
| Extension for crop production | = 1 if household had access to extension service for crop production |
| *Prices* | |
| Commercial price of urea | Median price of urea in the enumeration (MKW/kg) |
| Laspeyres spatial price index | Laspeyres spatial price index (base = national price in March) |
| *Household geo-variables* | |
| Distance to nearest road | Distance from house to the nearest road (Km) |
| Distance to tobacco auction floor (Km) | Distance from house to nearest tobacco auction floor (Km) |
| Distance to boma (Km) | Distance from house to main district market (boma) in district in where household lives (Km) |
| Distance to weekly market (Km) | Distance from house to the nearest weekly market (Km) |
| Northern region | = 1 if household lives in the Northern region |
| Central region | = 1 if household lives in the Central region |
| Tropical-warm/subhumid | = 1 if household is located in the tropical-warm/subhumid agro-ecological zone |
| Tropical-cool/semiarid | = 1 if household is located in the tropical-cool/semiarid agro-ecological zone |
| Tropical-cool/subhumid | = 1 if household is located in the tropical-cool/subhumid agro-ecological zone |

unobserved time-invariant factors include such factors as household's risk aversion and management ability, and the time-varying factors include such variables as household's health status, political turmoil and so forth.

### *4.1. Measures of agricultural productivity and welfare*

Agricultural productivity is measured by maize yield and value of crop output per hectare. Maize yield is an important productivity measure because maize is the staple and the most widely cultivated crop in Malawi – it is cultivated by about 90 per cent of farmers on 70 per cent of their farm plots (NSO, 2012). In addition to maize, most households produce other food crops such as groundnut, pigeon pea and so forth, and cash crops such as tobacco. In order to account for the production of these other food and cash crops in the analyses, the study also measures agricultural productivity of a household as the monetary value of all crops produced by the household per hectare of land cultivated by the household. For a given household, the value of crops produced per hectare of land cultivated is estimated as follows: 1) multiplying the output harvested of each cultivated crop by the community-level median price of the cultivated crop; 2) summing the values of all the crops cultivated; and 3) dividing by the total hectares of land cultivated.

We measure welfare in terms of both poverty and food insecurity. The poverty measures of welfare include per capita annual consumption expenditure, relative deprivation in terms of per capita consumption expenditure, poverty gap and severity of poverty. The annual consumption expenditure variable is an aggregate expenditure variable made up of expenditures on food and non-food products. A more elaborate description of the construction of the consumption expenditure variable can be found in World Bank (2013).

Relative deprivation in terms of consumption expenditure was measured with Stark and Taylor's (1989) index. The greater the index is for a given household, the more deprived the household is relative to other households in terms of per capita consumption expenditure. Poverty gap and severity of poverty are measured by the Foster-Greer-Thorbecke index (Foster, Greer, & Thorbecke, 1984), where the latter is the square of the former. The Foster-Greer-Thorbecke index is typically a summary statistic but, following Mason and Smale (2013), it is made amenable for use in a regression model by constructing a household specific version of the index. Both poverty gap and severity of poverty take values of zero for non-poor households and a fraction for poor households.

The food security measures consist of per capita caloric intake and relative deprivation based on per capita caloric intake. Caloric intake is the total amount of calories contained in all the food items consumed by the household at home and away-from-home within the past week. The study further generated a measure of welfare called *composite welfare* that combines households' poverty and food security status. *Composite welfare* is an ordered categorical variable defined as one for poor and food insecure households; two for non-poor but food insecure or poor but food secured households; and three for non-poor and food secured households.

### *4.2. Choice of estimators*

Depending on the measure of welfare, the effect of agricultural expenditure on welfare is estimated with a household Fixed Effects (FE) estimator, a two-part estimator, or ordered probit estimator with Mundlak-Chamberlain (MC) device (Mundlak, 1978). The household FE estimator is used when welfare is measured by per capita annual consumption expenditure, relative deprivation in terms of per capita consumption expenditure, per capita caloric intake or relative deprivation in terms of per capita caloric intake because these models are linear. The two-part estimator is used when the measure of welfare is either poverty gap or poverty severity; and the ordered probit estimator is used when welfare is measured by the composite measure.[1] The first part of the two-part estimator estimates the probability of being poor using a logit estimator while the second part estimates the extent of poverty conditional on being poor, using the fractional logit estimator (Belotti, Deb, Manning, & Norton, 2015). The two-part estimator is used instead of a simple fractional estimator because poverty and severity of poverty are corner solution outcomes – the dependent variables take on values of zero for non-poor households and continuous (fraction) for poor households (Wooldridge, 2010). Thus the two-part estimator accounts for the fact that there may be differences in how agricultural productivity affect the probability of being poor and how it affects the extent of poverty (Belotti et al., 2015; Wooldridge, 2010). The use of the two-part estimator also allows us to account for the fact that the continuous part of poverty gap and food insecurity are only observed for poor households.

### *4.3. Potential endogeneity of agricultural productivity in the welfare models*

In order to obtain consistent estimates of the effect of agricultural productivity on the welfare of households, the correlation between the observed covariates in Equation (3a) and the unobserved time-invariant and time-varying factors must be controlled for. Because the data used in the analyses is panel, household fixed effects (FE) and the MC device are used to control for unobserved heterogeneity in the models depending on the welfare measure. FE is used when the model is linear, that is when welfare is measured by per capita consumption expenditure, relative deprivation in terms of consumption expenditure, per capita caloric intake or relative deprivation in terms of caloric intake; and MC device is used when the model is non-linear, that is when welfare is measured by poverty gap or severity of poverty. The MC device is relevant in non-linear models; and it is analogous to fixed effects in linear models.

Even after controlling for unobserved heterogeneity using either household FE or MC device, the estimate of agricultural productivity on welfare will still be inconsistent if $A_{it}$ is correlated with $\mu_{it}$, unobserved time-varying factors. The correlation between $A_{it}$ and $\mu_{it}$ could potentially come from three sources: errors in the measurement of agricultural productivity, reverse causality between agricultural productivity and welfare, and omitted variable bias. Plots size in our dataset is measured using GPS estimates, so we are confident that agricultural productivity is measured with minimal errors. Reverse causality is avoided by ensuring that the survey instrument was administered after harvesting of agricultural products was completed, as discussed earlier in the discussion of our dataset. Hence the direction of the effect will be agricultural productivity on welfare rather than vice versa.

Omitted variable bias, however, could be a problem since welfare and agricultural productivity are both potentially affected by unobserved institutional and location factors that may change over time (Dzanku, 2015; Keswell, Burns, & Thornton, 2012). We use two formal approaches to assess the robustness of our results to omitted variable bias resulting from unobserved time-varying factors. The first is an approach developed by Oster (2015) that is based on the assumption that observables and unobservables have the same explanatory power in explaining the dependent variable. Oster (2015) demonstrates that the '*controlled estimate*' (the coefficient on the variable of interest from the model with the full set of observable controls) and the '*bias-adjusted estimate*' (the coefficient on the variable of interest after controlling for both observables and unobservables) provide a useful range that can be used to examine the robustness of the '*controlled estimate*' to omitted variable bias. The '*controlled estimate*' is robust to omitted variable bias if the range does not contain zero and is within the confidence interval of the '*controlled estimate*'. The Oster (2015) approach considers not only coefficient movements but also movements in R-squared values when including additional independent variables. The *'bias-adjusted estimate'* is calculated as:

$$\beta^* = \beta^c - (\beta^{uc} - \beta^c) * \frac{R_{max} - R^c}{R^c - R^{uc}} \tag{4}$$

where $\beta^c$ and $R^c$ are the '*controlled estimate*' and the $R^2$ of the regression from which the '*controlled estimate*' was obtained respectively; and $\beta^{uc}$ and $R^{uc}$ are respectively the coefficient estimate and $R^2$ of the uncontrolled regression, the regression in which the variable of interest is the only independent variable. $R_{max}$ is the $R^2$ of a hypothetical regression in which both observables and unobservables are controlled for, which is clearly unknown. Oster (2015) suggests that $R_{max} = \min\{2.2R^c, 1\}$. The $R^c$ from our models are such that $2.2R^c>1$, suggesting that we choose $R_{max} = 1$ based on Oster (2015).

Meanwhile González and Miguel (2015) argues that $R_{max}$ of 1 or close to 1 is likely to be too high for poverty analyses in developing countries where consumption and income levels are measured with a considerable level of error. Based on relatively high quality US data, González and Miguel (2015) suggested that $R_{max}$ should not be greater than 0.9. An $R_{max}$ of 0.89 was therefore chosen for our analyses.

Second, we use the control function approach to formally test for the potential endogeneity of agricultural productivity in the welfare models. This is done in order to consider the possibility of the underlying assumption of Oster (2015) not holding, and also to consider other potential sources of endogeneity. The control function approach requires the inclusion of instrumental variables(s) (IV) in the reduced form model of agricultural productivity (Wooldridge, 2010). We use the duration (days) of the photosynthetic period over the growing season as our IV. We expect this variable to be a strong instrument because it measures duration of the process by which green plants use sunlight to synthesise foods from carbon dioxide and water, and thus should be positively correlated with agricultural productivity. Many experiments in the agronomic literature provide a very strong indication of the positive relationship between photosynthesis and yield (Ainsworth et al., 2002; Bender, Hertstein, & Black, 1999; Long, Zhu, Naidu, & Ort, 2006; Mitchell et al., 1999). For instance, Bender et al. (1999) and Mitchell et al. (1999) indicate that a 50 per cent increase in photosynthesis is associated with a 35 per cent increase in grain yield. Apart from crop yield, the duration of the photosynthetic period is unlikely to directly affect welfare of rural agricultural households through any other channels. This is especially true when we control for other geo-spatial variables such as agro-ecological zone, distance to market, along with prices and household demographics, and using household-level FE and MC device to deal with remaining unobserved heterogeneity.

### *4.4. Data*

Data used in this article come from the Malawi Integrated Household Panel Survey (IHPS). IHPS is a two-wave panel dataset collected by the National Statistical Office of Malawi (NSO) with support from the World Bank Living Standards Measurement Study – Integrated Surveys on Agriculture (LSMS-ISA) programme. The survey for the first wave of the data covered 3247 households (hereafter baseline households) in the 2009/2010 agricultural year. The sampling was representative at the national, regional and urban/rural levels. The survey for the second wave of the data was conducted in the 2012/2013 agricultural year and attempted to track and resample all the baseline households as well as individuals (projected to be at least 12 years) that split-off from the baseline households between 2010 and 2013 as long as they were neither guests nor servants and are still living in mainland Malawi. Once a split-off individual was located, the new household that he/she formed or joined was also brought into the second wave. In all, a total of 4000 households were traced back to 3104 baseline households. A majority, 76.80 per cent, of the 3104 baseline households did not split over time; 18.49 per cent split into two households; and the rest (4.70%) split into three to six households. Considering the 20 baseline households that died in their entirety between 2010 and 2013 and the fact that 4000 households could be traced back to 3104 baseline households, the data has an overall attrition rate of only 3.78 per cent at the household level.[2]

We drop all non-agricultural households (580 and 845 households in the first and second waves respectively), as well as urban agricultural households (370 and 438 households in the first and second waves respectively). The urban agricultural households were dropped because farming in Malawi is predominantly rural. In order to avoid reverse causality in our welfare models, we also dropped the households for which questions about their food and non-food consumption were asked before the harvesting of agricultural products. Households for which questions about food and non-food consumption were asked before harvesting and those for which the questions were asked after harvesting constituted different panels of the data, and the households in each of the panels were randomly selected (panels A and B in the Malawi LSMS parlance). Hence dropping the former households from the data used in this study does not pose any significant biases to our estimates and removes the potential for reverse causality in our estimates. In the end a panel of 2023 households, 946 households in the first wave and 1077 household in the second wave, was used for the analyses. Data for the instrumental variable, duration of the photosynthetic period, for the two growing seasons (2009/2010 and 2012/2013) was obtained from the MODIS Land Cover Group of Boston University (http://www.bu.edu/lcsc/data-documentation/) upon request, and matched onto the data for the other variables using GPS coordinates.

## 5. Results

### 5.1. Descriptive statistics

The descriptive statistics of the variables in the welfare models are presented in Table 2. The statistics indicate that agricultural productivity increased among rural agricultural households between 2010 and 2013: value of crops per hectare increased by 16.22 per cent (from MKW 44440 [US$123.5] to MKW 51650 [US$143.6]) and maize yield increased by 22.82 per cent (from 1340kg/ha to 1650kg/ha). The significant increase in agricultural productivity could have been due to increased use of inorganic fertiliser and other physical inputs, as well as to farmers getting better at combining inputs in crop production.

Table 2 also shows that, between 2010 and 2013, the poverty status of rural agricultural households in Malawi improved significantly in all dimensions (level, relativity, depth and severity) – per capita consumption expenditure increased by about 11.68 per cent; relative deprivation in terms of consumption expenditure decreased by about 4.15 per cent; and poverty gap and severity of poverty decreased by four and two percentage points respectively. The average per capita caloric intake was 2450 Kcal in the 2009/2010 agricultural year and 2360 Kcal in the 2012/2013 agricultural year. Compared to the minimum nutritional requirement of 2400 Kcal per day, the average rural household in Malawi is barely food secure in 2010 and food insecure in 2013.

### 5.2. Empirical results

Table 3 presents a summary of the results of the impact of agricultural productivity on the various measures of household welfare. The full model results are presented in the Supplementary Materials (Tables A1 to A6). The last column of Table 3 shows the range of the estimates based on the robustness check that follows Oster (2015). The range of estimates do not contain zero and the upper bounds are within the confidence interval of the '*controlled estimates*', suggesting that our estimates are robust to omitted variable bias (Freier, Schumann, & Siedler, 2015; González & Miguel, 2015; Nghiem, Nguyen, Khanam, & Connelly, 2015; Oster, 2015). The formal test of endogeneity using the control function approach also rejects the hypothesis that agricultural productivity is endogenous in our welfare models after controlling for omitted variable bias with household FE (or MC device) and a full set of observable controls. Hence, overall, our estimates are robust not only to omitted variable bias but also to other potential sources of endogeneity. Results of the endogeneity test using the control function approach are presented in Tables A7 and A8 of the Supplementary Materials.

### 5.3. Direct effect of agricultural productivity on welfare

As indicated under the conceptual framework, the estimates from our models are the *direct effects* of agricultural productivity on the welfare of agricultural households. The model results indicate that growth in agricultural productivity has the expected, significant, inverse relationship with all measures of poverty (Table 3 as well as Tables A1 and A3 in the Supplementary Materials). All things being equal, a one percentage increase in maize yield and the value of crops per hectare will increase per capita consumption expenditure by 0.132 per cent and 0.096 per cent respectively; reduce relative deprivation in terms of consumption expenditure by 0.058 per cent and 0.042 per cent respectively;

**Table 2.** Descriptive statistics

| | Pooled | 2009/2010 agricultural year | | | 2012/2013 agricultural year | | |
|---|---|---|---|---|---|---|---|
| Variables | Mean | Mean | Median | SD | Mean[a] | Median | SD |
| Dependent Variables (measures of welfare) | | | | | | | |
| *Poverty measures* | | | | | | | |
| Per capita consumption expenditure ('000) | 129.16 | 121.62 | 95.83 | 97.81 | 135.83*** | 108.92 | 93.57 |
| Relative deprivation in terms of consumption expenditure (`000) | 150.15 | 153.53 | 164.70 | 31.69 | 147.15*** | 157.64 | 35.33 |
| Poverty gap | 0.11 | 0.13 | | 0.20 | 0.09*** | | 0.17 |
| Severity of Poverty | 0.05 | 0.06 | | 0.11 | 0.04*** | | 0.09 |
| *Food security measures* | | | | | | | |
| Per capita caloric intake ('000) | 2.4 | 2.45 | 2.13 | 1.28 | 2.36 | 2.09 | 1.20 |
| Relative deprivation in terms of caloric intake (`000) | 1.86 | 1.77 | 1.96 | 0.69 | 1.95*** | 2.13 | 0.67 |
| *Poverty and food security measure* | | | | | | | |
| Composite Welfare | 2.03 | 2.00 | 2.00 | 0.85 | 2.06 | 2.00 | 0.84 |
| Independent variables | | | | | | | |
| *Agricultural Productivity* | | | | | | | |
| Value of crops per hectare ('000 MWK) | 48.26 | 44.44 | 27.77 | 46.86 | 51.65 *** | 35.45 | 60.27 |
| Maize yield ('000 KG/HA) | 1.51 | 1.34 | 1.01 | 1.14 | 1.65*** | 1.17 | 1.94 |
| *Other sources of income* | | | | | | | |
| Number of livestock | 0.30 | 0.28 | 0.05 | 0.84 | 0.33 | 0.05 | 1.02 |
| Net income from tree/permanent crop production ('000 MWK) | 2.31 | 1.49 | 0.00 | 4.00 | 3.03*** | 0.00 | 12.64 |
| Net income from off-farm enterprise ('000 MWK) | 22.32 | 11.17 | 0.00 | 50.97 | 32.20*** | 0.00 | 109.17 |
| Agricultural wage (MWK/DAY) | 25.82 | 19.52 | 0.00 | 42.45 | 31.39*** | 0.00 | 64.74 |
| Other sources of income (MKW) | 32.5 | 27.6 | 0.00 | 45 | 36.80*** | 0.00 | 49 |
| Household characteristics | | | | | | | |
| Household size | 5.08 | 4.9 | 5.00 | 2.26 | 5.23*** | 5.00 | 2.21 |
| Dependency ratio (%) | 122.56 | 124.54 | 100.00 | 86.40 | 120.8 | 100.00 | 87.58 |
| Male-headed households | 0.74 | 0.74 | 1.00 | 0.43 | 0.74 | 1.00 | 0.43 |
| Age of HH head | 43.49 | 43.77 | 40.00 | 16.48 | 43.24 | 40.00 | 15.41 |
| Education of the most educated HH member | 6.98 | 6.54 | 7.00 | 3.47 | 7.38*** | 8.00 | 3.10 |
| Household landholding (Ha) | 0.78 | 0.74 | 0.61 | 0.60 | 0.82 | 0.57 | 6.03 |
| Owns crop storage house (%) | 16 | 18 | 0.00 | 0.40 | 13*** | 0.00 | 0.34 |
| Accessed credit (%) | 17 | 10 | 0.00 | 0.30 | 23*** | 0.00 | 0.41 |
| Extension for crop production (%) | 53 | 0.4 | 0.00 | 0.49 | 66*** | 1.00 | 0.48 |
| Prices | | | | | | | |
| Price of urea (MWK/KG) | 222.63 | 223.2 | 232.02 | 22.87 | 222.12 | 240.00 | 47.32 |
| Laspeyres spatial output price index | 86.86 | 90.82 | 90.82 | 8.45 | 83.36*** | 82.06 | 7.26 |
| Household geo-variables | | | | | | | |
| Distance to nearest road (KM) | 9.81 | 9.47 | 5.33 | 9.65 | 10.11 | 6.00 | 9.95 |
| Distance to tobacco auction floor (Km) | 77.91 | 77.26 | 71.57 | 50.31 | 78.5 | 73.00 | 49.77 |
| Distance to boma (Km) | 38.21 | 47.7 | 46.42 | 26.94 | 29.81*** | 27.00 | 25.37 |
| Distance to weekly market (Km) | 4.38 | 4.57 | 4.00 | 5.71 | 4.21 | 3.00 | 6.37 |
| Northern region | 0.12 | 0.12 | 0.00 | 0.42 | 0.11 | 0.00 | 0.41 |
| Central region | 0.43 | 0.42 | 0.00 | 0.48 | 0.43 | 0.00 | 0.49 |
| Tropical-warm/subhumid | 0.27 | 0.27 | 0.00 | 0.45 | 0.28 | 0.00 | 0.45 |
| Tropical-cool/semiarid | 0.18 | 0.18 | 0.00 | 0.37 | 0.18 | 0.00 | 0.37 |
| Tropical-cool/subhumid | 0.03 | 0.03 | 0.00 | 0.24 | 0.02 | 0.00 | 0.23 |
| Graded/Graveled | 0.27 | 0.24 | 0.00 | 0.44 | 0.30*** | 0.00 | 0.44 |
| Dirt road (maintained) | 0.53 | 0.54 | 0.00 | 0.50 | 0.52 | 1.00 | 0.50 |
| Dirt track | 0.05 | 0.06 | 0.00 | 0.25 | 0.04 | 0.00 | 0.17 |

*Notes*: [a]Stars indicate significant difference in mean between 2009/2010 and 2012/2013 agricultural years; $*p < 0.1$; $**p < 0.05$; $***p < 0.01$.

**Table 3.** Elasticity of agricultural productivity on household welfare

| Measure of Agricultural Productivity | Measure of household welfare | Estimates | Range of Estimates [based on Oster (2015)][a] |
|---|---|---|---|
| Log of maize yield | *Poverty measures* | | |
| | Log of per capita consumption expenditure | 0.132*** (0.020) | [0.132 0.173] |
| | Log of relative deprivation | −0.058*** (0.009) | [−0.058–0.076] |
| | Poverty gap | −0.034*** 0.006) | – |
| | Severity of poverty | −0.017*** (0.004) | – |
| | *Food security measures* | | |
| | Log of calories consumed per capita | 0.060** (0.023) | [0.060 0.107] |
| | Log of relative deprivation | −0.036 (0.024) | [−0.036–0.085] |
| | *Composite welfare*[b] | | |
| | Probability of being poor and food insecure | −0.057*** (0.017) | – |
| | Probability of being non-poor and food secure | 0.060*** (0.018) | – |
| Log of value of crop per ha | *Poverty measures* | | |
| | Log of per capita consumption expenditure | 0.096*** (0.017) | [0.096 0.130] |
| | Log of relative deprivation | −0.042*** (0.007) | −0.042–0.058] |
| | Poverty gap | −0.019*** (0.004) | – |
| | Severity of poverty | −0.008*** (0.002) | – |
| | *Food security measures* | | |
| | Log of calories consumed per capita | 0.054*** (0.019) | [0.054 0.094] |
| | Log of relative deprivation | −0.040* (0.020) | −0.040–0.081] |
| | *Composite welfare*[b] | | |
| | Probability of being poor and food insecure | −0.043*** (0.010) | – |
| | Probability of being non-poor and food secure | 0.046*** (0.011) | – |

*Notes*: [a]Psacalc of Oster (2015) only applies to linear regression. [b]The estimates of composite welfare presented in this table are the marginal effects of the probability of being in the first (poor and food insecure) and third (non-poor and food secure) categories. See Tables A7 and A8 for the estimates in the full model that has estimates of all the three categories. $*p < 0.1$; $**p < 0.05$; $***p < 0.01$.

reduce the poverty gap by 0.034 and 0.019 percentage points respectively; and reduce the severity of poverty by 0.017 and 0.008 percentage points respectively.

The inverse effect of agricultural productivity on poverty is also reflected in its effect on poverty rate and the number of people that can be lifted out of poverty (Table 4).[3] These estimates are based on only the *direct effect* estimates and should therefore be interpreted as lower bound estimates. The simulation results indicate that a 50 per cent increase in maize yield will reduce the poverty (ultra-poverty) rate among rural agricultural households by at least 6.77 (2.54) percentage points from 40.78 per cent (11%) to 34.01 per cent (8.46%).[4] The 50 per cent increase in maize yield will correspondingly lift at least 622,015 people out of poverty and 281,718 people out of ultra-poverty. It should be noted from the simulation results that the gains in poverty reduction accruing from incremental changes in agricultural productivity taper off around 55 per cent. This could be because beyond a 55 per cent increase in agricultural productivity the remaining poor households are so far below the poverty line, with very little land to cultivate, that further increases in agricultural productivity are unable to lift them above the poverty line.

The direction of the *direct effect* of agricultural productivity on the welfare measures support the widely-held notion that growth in agricultural productivity could be an effective channel for

**Table 4.** Effect of increases in agricultural productivity on the transition of households out of poverty

| Increase in maize yield | % of poor households in 2013 | | % of Ultra-poor households in 2013 | | Number of people lifted out of poverty | | Number of people lifted out of ultra-poverty | |
|---|---|---|---|---|---|---|---|---|
| | Maize yield | Value of crop | Maize yield | Value of crop | Maize yield | Value of crop | Maize yield | Value of crop |
| 0% | 40.78 | 40.78 | 11.00 | 11.00 | – | – | – | – |
| 5% | 35.74 | 35.19 | 9.39 | 8.61 | 555,969.31 | 573,745.06 | 253,024.14 | 295,786.78 |
| 10% | 35.45 | 35.19 | 9.26 | 8.39 | 555,969.31 | 573,745.06 | 260,351.78 | 295,786.78 |
| 15% | 35.45 | 34.99 | 9.26 | 8.39 | 555,969.31 | 585,601.25 | 260,351.78 | 295,786.78 |
| 20% | 35.19 | 34.99 | 9.11 | 8.39 | 567,825.50 | 585,601.25 | 260,351.78 | 295,786.78 |
| 25% | 35.08 | 34.70 | 9.11 | 8.39 | 571,433.63 | 598,899.56 | 260,351.78 | 295,786.78 |
| 30% | 34.99 | 34.67 | 9.11 | 8.27 | 576,370.13 | 598,899.56 | 260,351.78 | 302,815.31 |
| 35% | 34.77 | 34.67 | 9.05 | 8.10 | 581,876.44 | 598,899.56 | 260,351.78 | 302,815.31 |
| 40% | 34.62 | 34.67 | 8.65 | 8.10 | 588,786.94 | 598,899.56 | 270,491.66 | 302,815.31 |
| 45% | 34.36 | 34.47 | 8.65 | 8.10 | 601,266.94 | 603,817.88 | 270,491.66 | 302,815.31 |
| 50% | 34.01 | 34.38 | 8.46 | 7.97 | 622,015.25 | 603,817.88 | 281,718.41 | 310,142.97 |
| 55% | 33.95 | 34.27 | 8.34 | 7.97 | 622,015.25 | 610,175.81 | 288,746.94 | 310,142.97 |
| 60% | 33.86 | 34.16 | 8.00 | 7.94 | 626,781.38 | 616,297.88 | 308,266.31 | 311,868.25 |
| 65% | 33.76 | 34.16 | 7.94 | 7.94 | 626,781.38 | 616,297.88 | 311,868.69 | 311,868.25 |
| 70% | 33.76 | 34.16 | 7.79 | 7.81 | 626,781.38 | 616,297.88 | 320,494.97 | 311,868.25 |
| 75% | 33.62 | 34.11 | 7.79 | 7.81 | 631,964.19 | 619,649.56 | 320,494.97 | 311,868.25 |
| 80% | 33.17 | 34.11 | 7.64 | 7.81 | 657,617.88 | 619,649.56 | 320,494.97 | 311,868.25 |
| 85% | 33.17 | 34.06 | 7.64 | 7.81 | 657,617.88 | 622,357.19 | 320,494.97 | 311,868.25 |
| 90% | 33.08 | 34.01 | 7.64 | 7.81 | 662,993.94 | 625,088.63 | 320,494.97 | 311,868.25 |
| 95% | 33.08 | 34.01 | 7.64 | 7.81 | 662,993.94 | 625,088.63 | 320,494.97 | 311,868.25 |
| 100% | 33.03 | 34.01 | 7.56 | 7.81 | 662,993.94 | 625,088.63 | 325,017.94 | 311,868.25 |
| ***Raising productivity of all households to:*** | | | | | | | | |
| Quarter of district highest | 32.16 | 31.17 | 6.60 | 6.52 | 728,040.63 | 763,563.25 | 327,458.78 | 374,495.47 |
| Half of district highest | 28.98 | 28.44 | 5.95 | 5.13 | 863,750.31 | 890,375.00 | 350,718.66 | 420,365.44 |
| Three-quarters of district highest | 27.29 | 27.34 | 5.23 | 4.76 | 909,683.69 | 934,795.81 | 377,188.38 | 424,577.97 |
| District highest (full potential) | 25.32 | 26.69 | 5.14 | 4.76 | 1,021,293.50 | 966,361.06 | 382,145.03 | 424,577.97 |

improvement in the welfare of rural agricultural households in Malawi. It should however be noted that the *direct effects* and the associated number of people lifted out of poverty are small in terms of economic magnitude, and the increase in poverty reduction through agricultural growth tapers off at around a 55 per cent increase. Similar significant but small *direct effects* of agricultural productivity on measures of poverty have been observed in other parts of SSA. Dzanku (2015) observed that a percentage increase in value of output per ha will increase per capita consumption expenditure by 0.207 per cent, all things being equal. In Tanzania, Sarris et al. (2006) estimated the elasticity of per capita consumption expenditure with respect to agricultural productivity (value of output per ha) to be 0.15 in rural households in the Kilimanjaro region.

Among other things, the economic magnitude of the *direct effect* observed in this study is small for two main reasons. First, and perhaps most importantly, because Malawi is at import parity, it could be that the increase in agricultural productivity does not have a big impact on food prices (Ricker-Gilbert, Mason, Darko, & Tembo, 2013). Meanwhile, Otsuka (2000) and Biswanger and Quinzon (1986) observe that much of the positive impact that the green revolution technology in Asia had on poverty and inequality resulted from lower food prices accruing from output expansion. Schuh (2000) also suggests that the greatest achievement of world agriculture in the fight against poverty came via the supply of affordable food to the masses; and Datt and Ravallion (1998) indicated that absolute poverty levels can be largely impacted by even smaller changes in food prices. The second reason why the economic magnitude of the direct effect is small could be the fact that the average smallholder farm is just 0.42 hectares, meaning very high productivity increases will be needed to have a meaningful *direct* impact on per capita household consumption for an average family of five members.

We also find that growth in agricultural productivity also has the expected, inverse *direct effect* on food insecurity and the composite measure of welfare (Table 3 as well as Tables A2, A4, A5 and A6 in the Supplementary Materials). A one percentage increase in maize yield and value of output per hectare will, all things being equal, increase caloric intake by 0.06 per cent and 0.054 per cent respectively. For the composite measure of welfare, the estimates indicate that a percentage increase in maize yield and value of crops per hectare will decrease the probability of being poor and food insecure by 0.057 per cent and 0.043 per cent respectively; and increase the probability of being non-poor and food secure 0.060 per cent and 0.046 per cent respectively.

### 5.4. *Spillover effects of agricultural productivity on welfare*

Though not directly calculated in our simulation, we use estimates from Benin et al. (2008) to estimate the growth multiplier between the agricultural sector and the rest of the Malawian economy. Benin et al. estimate the multiplier to be 1.11, so with the agricultural GDP of US$ 962.16 million (in constant 2010 prices), and the share of crop production in the agricultural GDP of Malawi (83%), we estimate the *spillover effects* of a percentage increase in agricultural productivity on the rest of the economy to be US$ 87,844,966 (that is [(0.83*962157345.64)*0.11]); where (0.83*962157345.64) is the additional increase in agricultural GDP resulting from a percentage increase in crop output, and 0.11 is the increase in the GDP of the non-agricultural sector that results from a dollar increase in the GDP of the agricultural sector. Although this spillover effects look big overall, on per capita (number of rural agricultural population, about 11.36 million) basis, it is just US$ 7.73. Moreover, the extent to which rural agricultural households benefit from the *spillover effects* depends on the level of their participation in the non-farm sector of the economy; the higher their participation, the higher the welfare benefits. The data used in this study suggests that only about 18 per cent of agricultural households in both 2010 and 2013 participated in the non-farm sector; and the average income that these households obtained from their non-farm income generating activities is only MKW 22,320 (US $ 62.03) in 2010 and MKW 32,200 (US$ 89.49) in 2013. Hence, like the *direct effects*, the *spillover effects* in the non-farm sector is small.

Ultimately, where do the findings of this study fit in the broader discourse of the potential role of agriculture in improving the welfare of households in Malawi and other countries in SSA; and how does it contribute to, or advance, the discourse? This study points to an important aspect of the welfare-improving role of agriculture that is worth attention. It reveals that it would be challenging for agriculture to bring about the needed improvement in the welfare of rural households if attention is given solely to increasing agricultural productivity through yield increases. In fact, a look at the success stories of agriculture-led poverty reduction in Asia (during the Green Revolution) and SSA reveals that the successes were realised mainly through means (such as extensification, commercialisation and/or crop diversification) other than mere increases in agricultural (land) productivity. Binswanger and Quizon (1986) and Otsuka (2000) demonstrates that the welfare-enhancing effects of the Green Revolution technology in Asian countries such as Thailand and Nepal came mainly from lowered food prices that resulted from the expansion of farmland. In Malawi, Mukherjee and Benson (2003) find that land and crop diversification significantly reduce poverty in rural areas; and that households that grow tobacco (a high-value crop) are significantly less likely to be poor. Households that moved out of poverty in Kenya between 1997 and 2007 more than doubled their landholdings and cultivated 70 per cent more land in 1997 than in 2007 (Muyanga, Jayne, & Burke, 2010). Kristjanson, Mango, Krishna, Radeny, and Johnson (2010) reports that 23 per cent of households that graduated out of poverty attributed their success to increased land cultivation; 49 per cent attributed it to crop diversification; and in areas of low potential for crop production, 50 per cent of the households attributed their success to diversification away from maize to crops of higher value. Cunguara (2008) reports that between 2002 and 2005, households that moved out of poverty in Mozambique increased the land cultivated by 10 per cent. In Zambia, households moving out of poverty increased their landholdings from 5ha to 23ha (Banda, Hamukwala, Haggblade, & Chapoto, 2011). It is also worth mentioning that, agricultural extensification is not likely to be realised in most parts of SSA because the average landholding and farm size is very small for most agricultural households (Harris & Orr, 2013). The current landholding in Malawi for instance is less than a hectare per household, and with increasing population pressure, landholdings are likely to get smaller in the future. Hence crop diversification from crops of low value to high-value crops appears to be the channel that can complement growth in agricultural (land) productivity to bring about the needed agricultural-led improvement in the living standards of rural agricultural households in SSA.

Given the significant but small effect that increases in agricultural productivity have on the welfare of rural agricultural households, and the fact that agricultural extensification is not likely to be realised, crop production ought to be supported by other policy moves. This study finds that other important determinants of the welfare of rural agricultural households include household size, landholdings, ownership of crop storage house, and prices of consumable goods.

## 6. Conclusions

This article estimates the extent to which agricultural productivity affects the welfare of agricultural households in Malawi using two waves of a nationally representative panel data from rural Malawi. Welfare was measured in terms of poverty and food insecurity, and agricultural productivity was measured by maize yield and value of crop output per hectare. The poverty measures considered included per capita consumption expenditure, relative deprivation in terms of consumption expenditure, poverty gap and severity of poverty; and the food security measures included caloric intake and relative deprivation in terms of caloric intake.

The results indicate that increasing agricultural productivity has a statistically significant and positive effect on the welfare of rural agricultural households in Malawi. However, the impact (both the *direct effects* and the economy-wide *spillover effects)* is small in terms of economic magnitude. Hence, overall, this study suggest that agricultural productivity will have to increase by a large amount in order to bring about the needed improvement in the welfare of rural agricultural households. Thus, rural household welfare-improving initiatives must go beyond the confines of increasing agricultural (land) productivity. Other findings of this study suggest that non-agricultural measures such as the promotion of off-farm income-generating activities, smaller household size, and ownership of a crop storage house and favourable prices of consumable goods should also be considered as possible welfare-improving initiatives.

It is important to note that the estimated impacts found in this article relate to the ability of rural households to increase agricultural productivity within a season. Maintaining these increases over time is an additional challenge. For example, if maize yields increase due to adoption of a new variety of maize in the current year, will this variety be able to maintain its productivity in the face of a climate that is becoming drier and hotter over time? Sustainably increasing crop productivity and having that translate into poverty reduction will require investment in research, extension, and market development.

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## Disclosure statement

No potential conflict of interest was reported by the authors.

## Notes

1. The two-part estimator is implemented using the *twopm* command in stata (Belotti et al., 2015). *Twopm* has a variety of estimators that can be used for the first and second parts depending on research interest. More importantly, marginal effects for the combined model can be easily recovered using the margins command.
2. Attrition bias in the data could not be tested for in our data because there are no regression-based tests for attrition when fixed effects or MC devise models are used with a panel of only two waves. A panel of more than two-waves are required for such tests (Mason & Smale, 2013; Wooldridge, 2010). That notwithstanding, the study is confident that attrition bias is not likely to be a concern because as indicated earlier, the attrition rate is only 3.78 per cent at the household level.
3. Estimates of yield gap reported by Global Yield Gap Atlas (www.yieldgap.org), indicate that maize yield (and yield of cereals in general) in countries such as Zambia, Tanzania, Uganda, Kenya and Ethiopia that are in the same geographical area as Malawi can be increased by over 300 per cent. Hence the range of the incremental changes in agricultural productivity (0–100%) used in the simulation analysis is reasonable.
4. The simulations assume that there are no general equilibrium effects in the sense that changes in the determinants do not affect the partial regression parameters or other exogenous variables. This assumption is (highly) likely to be valid because the simulated changes are incremental (0%, 5%, 15%, . . ., 100%). The results should therefore be interpreted with this caveat in mind.

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