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Thomas Ferreira

Abstract

Malawi is a low-income country where the majority of the poor live and work in smallholder agriculture. In settings like these, schooling is believed to be a valuable tool in lifting people out of poverty. Yet, little is known about how schooling affects agricultural productivity. The effect of education on smallholder agricultural production has been estimated before but this paper contributes to the literature by estimating, for the first time, the causal effects of education on agricultural productivity using an instrumental variable approach (IV). The introduction of free primary education (FPE) and the age of paternal orphanhood are used as IV's for education. The instruments are shown to calculate local average treatment effects for individuals who only entered school due to FPE and only left school due to paternal orphanhood. It is found that there are large differences in returns to education between the subgroups. Returns are low and insignificant when FPE is used as an IV but they are larger and there is a significant effect when age of paternal orphanhood is used. Thus, while education can have large effects on agricultural productivity, this is not so for individuals specifically targeted by large scale expansions in educational access.

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1 Introduction

Malawi is a poor country with a small formal sector and large informal sector. In 2010 approximately 70% of the employed worked in subsistence agriculture.[1] Approximately 55% of employed individuals worked in household agriculture while another 17% worked as ganyu labourers, which are casual labourers mostly associated with household agriculture. At the same time, the rural headcount poverty rate was around 56.6% (NSO, 2012a). With the majority of the population living in poverty while working in subsistence agriculture, increasing agricultural productivity is key to addressing poverty.

For poverty alleviation, the importance of growth in the agricultural sector cannot be understated. Ravallion and Chen (2007) found that in China, to account for the reduction in poverty from 53% (1981) to 8% (2001), growth in the primary sector (mostly agriculture) had approximately a four times larger effect than growth in other sectors. A cross-country study of the relationship between agricultural output and poverty by Irz et al. (2001) found that for a typical low-income country with a headcount poverty rate of 40%, an annual growth rate of 2.17% in agricultural productivity was associated with a decrease in the headcount poverty rate of 10 percentage points in just 10 years. The authors also found that an increase in agricultural productivity of 1% was associated with a 12% increase in a country's Human Development Index (HDI). Christiaensen et al. (2011) note that increasing agricultural productivity is particularly effective at reducing extreme poverty, mainly because it is the sector in which the poor participate the most.[2]

It should come as no surprise that in Malawi growth in agricultural productivity is low. Between 2000 and 2005, the growth rate of GDP per capita in smallholder agriculture was -1.78% (Chirwa et al., 2008). Agricultural productivity growth was generally low across sub-Saharan Africa (SSA) in this period. Fuglie (2008) found that between 2000 and 2006, growth in total factor productivity (TFP) in agriculture in the region was the lowest of all regions in the world. SSA's average annual growth rate in TFP for the period 2000 to 2006 was estimated at 0.61%. For North and East Africa it was 1.56% while for Brazil and China it was 3.66% and 3.22% respectively.

One channel through which agricultural production can be increased is education. Numerous authors have hypothesized how education can affect production. Welch (1970) suggests that

[1] Estimates are based on own calculations from Malawi's Third Integrated Household Survey, which was conducted in 2010/2011.

[2] Extreme poverty is expressed as the squared poverty gap at the $1 per day poverty line.

education can work through two channels - a worker and an allocative effect. The worker effect refers to how education can make farmers more productive given the resources they have, while the allocative effect is the effect that education can have on farmers' ability to use and allocate resources more efficiently. Many authors have questioned the value of education in traditional agricultural settings and noted that education becomes more valuable in technologically advanced settings where the ability to, for example, adopt and learn to use new technologies becomes important (Welch (1970); Schultz (1975); Ram (1980)).

Asadullah and Rahman (2009) note that empirically there is only weak evidence that education really has positive effects on agricultural productivity. A concerning factor about the literature is a lack of causal interpretation. To estimate the effects of education on agricultural productivity, most studies have used Ordinary Least Squares (OLS) and/or Stochastic Production Frontier (SPF) methods which measure the role of education, either in the estimation of the agricultural production frontier or as an explanatory variable of inefficiency. None of the methods allow for causal interpretation, however, as they do not account for the endogeneity of education. Jamison and Moock (1984) attempted to control for endogenous factors in an OLS regression but questions around omitted variable bias will always be present in the absence of an experimental or quasi-experimental design.

This study fills this gap by estimating the causal effect of education on agricultural productivity using an instrumental variable (IV) approach for the first time. Two instruments are used for education. The first instrument uses the gradual introduction of free primary education (FPE) in the early 1990's in Malawi. The second instrument is the age of paternal orphanhood. The first represents relief from a credit constraint and the second an imposition of one. The IV estimates capture local average treatment effects (LATE). When using FPE as IV, the returns to education are measured for individuals who would not have entered schooling had it not become free. Using age of paternal orphanhood measures the returns for learners who would have stayed in school had their father not died.

Data from Malawi's Third Integrated Household Survey, conducted in 2010/11, is used for the analysis. Production functions for the cash yield of crops are estimated for Malawi's rainy season. The effect of education on formal sector earnings is also estimated using the instruments to gain a deeper understanding of the role that education plays in the country in general. The causal effect of education on earnings has also never been estimated for Malawi.

In agricultural production, the returns to education are low and insignificant when FPE is used as IV.[3] Returns are 1% when controlling for inputs and 3% when not. When age of paternal orphanhood is used as an IV, point estimates are higher and statistically significant with a 7% return when controlling for inputs and 9.3% when not. Returns to education are higher in the formal sector, however. Using FPE, the point estimate is 6.2% but insignificant. Using age of paternal orphanhood, the returns are significant and 15.4% to an extra year of education.

The difference in returns between the two groups captured by the IVs is striking. This study shows that while there can be returns to education in agricultural production, it is not guaranteed. Indeed, it is found that there are low returns to individuals, at whom the large expansions in education were especially targeted.

Section 2 provides a literature review on the relationship between education and agriculture from both a theoretical and empirical perspective. Section 3 provides a background on agriculture and education in Malawi. Section 4 discusses the data and methodology used. Section 5 provides the empirical results. This is followed by a discussion of the results in section 6 and section 7 concludes.

2 Literature Review

2.1 Model

This review of the literature starts with a short theoretical discussion on how education can affect production in general. Welch (1970) introduced a model whereby the potential effects of education in production can be divided into two categories: the worker and allocative effect. Firstly assume that production, Y, is a function of education, Z, and a set of other inputs, X.

$$Y = f(Z, X) \tag{1}$$

The marginal product of education is $\frac{\delta y}{\delta z}$. This captures the "worker effect" of education which is just the amount of extra production due to increases in education if all other inputs are held constant.

[3] When FPE is used as IV, point estimates are statistically similar to ordinary least squares estimates which are statistically significant.

In many cases producers produce more than one crop and they need to decide in what combination to produce them with the resources available. In agriculture for example, farmers need to decide what crops to grow. To illustrate this, define a total value function as:

$$Y = p_1 y_1(x_1) + p_2 y_2(x_2), \tag{2}$$

where Y is value of all crops produced, p_1 and p_2 refer to the prices of the crops y_1 and y_2. X is a given vector of inputs that needs to be allocated between different uses x_1 and x_2. The maximization of total value given X happens when firms are technically efficient and when:

$$\frac{\delta Y}{\delta x_1} = p_1 \frac{\delta y_1}{\delta x_1} - p_2 \frac{\delta y_2}{\delta x_2} = 0. \tag{3}$$

This implies that the maximization of sales happens when the values of the marginal products of y_1 and y_2 are the same. Now, if it is assumed that education has an allocative role, that is $x_1 = x_1(z)$, then the marginal product of education with regards to gross sales becomes:

$$\frac{\delta Y}{\delta z} = (p_1 \frac{\delta y_1}{\delta x_1} - p_2 \frac{\delta y_2}{\delta x_2}) \frac{\delta x_1}{\delta z}. \tag{4}$$

Ram (1980) introduced a modification to the above model by highlighting the role of information. He hypothesized that education decreases the marginal cost of acquiring information and also increases the marginal benefit from information. One implication of his theory was that the value of education is linked with the value of information. Thus in economic settings where information is more valuable, it would be worthwhile to get more educated. One example that he notes is that information is more useful to farm operators who make allocative decisions, than to hired workers who perform more mundane tasks. Thus, education would have higher returns for farm operators than labourers.

Ram (1980) also noted that in more dynamic agricultural settings, information and then schooling might have greater value. This point was also highlighted by Schultz (1975) and Welch (1970). In trying to explain the growth in the demand for education in the United States, Welch (1970) postulated that one of the two plausible explanations was "non-neutrality in production", which meant that the marginal product of education increased with advances in production methods and improvements in technology.

Schultz (1975) also highlighted this by comparing traditional and modern agriculture. In traditional settings where technology has not changed for generations, education is of little value. People have learnt from experience and children learn from their parents. In modern settings, farmers need to deal with a flow of changing technologies and economic conditions. In these circumstances there is a demand for the skills to deal with changes in production methods and new technologies.

New research has also highlighted the role that education has in communities. Educated farmers are more likely to be early adopters of new technologies, and this in turn leads to the diffusion of the technology to other less educated farmers in the community (see Foster and Rosenzweig (1995) and Weir and Knight (2000).

It has also been found that the allocation effect of education is present at the household level as well. Education increases the likelihood that farmers allocate their labour away from farming to non-agricultural activities for which there are higher returns (see Huffman (1980) and Fafchamps and Quisumbing (1999)). In this case education could even have negative effects on aggregate agricultural production.

2.2 Evidence of the returns to education in agriculture

Researchers have either used Ordinary Least Squares (OLS) or Stochastic Production Frontier (SPF) methods to measure the effects of education on agricultural production. Welch (1970) also showed that how inputs in estimation models are controlled for, could determine whether the worker or allocative effect is measured. When estimating the production of a single crop, only the worker effect will be measured. Total value production functions can measure the worker effect if other inputs are controlled for, and the worker plus allocative effect, if other inputs are not controlled for. What follows is a selective set of evidence from developing countries, firstly from meta-studies and secondly focusing more on individual studies.

Lockheed et al. (1980) did a survey of the evidence regarding farmer education and productivity for low income countries. They reviewed the evidence of 18 studies, done over 13 countries, with 37 datasets. They concluded that four years of education, when compared to zero years, increased farm productivity by 7.4%. The use of four years was motivated by the fact it is often seen as the minimum cycle for a basic education or for the acquisition of basic literacy. They also found that the effects of education were much higher when farmers used modern technologies. In modern agricultural environments they found that the average effect of four years of education was 9.5% while in traditional circumstances they found the average effect to be only 1.3%.

The Lockheed et al. (1980) results should be read with caution, though. In a comment on the study by Phillips (1987) he noted that only 56.4% of the studies reviewed in Lockheed et al. (1980) found a positive and significant effect while there was large regional variation in their findings. For a 0.05 significance level, 17 of 22 studies in Asia had positive significant effects while for Latin America, only 3 of 13 had positive significant effects. Only two studies in Africa, both on Kenya, were reported on. One found an insignificant effect while the other found a negative effect. In a reply Lockheed et al. (1987) noted that their methods were consistent with meta-analytical techniques. They also noted that the positive significant effects for Asia were plausibly due to modernisation in agriculture in the region. This suggests that educational returns may be context specific as returns only become relevant when production techniques are advanced.

Phillips (1994) conducted a meta-analysis of the existing evidence using an alternative method to Lockheed et al. (1980). Instead of averaging over all observations in all the datasets, he used the results of a number of studies as data points in a new cross-section. He used the same data as Lockheed et al. (1980) plus a number of additional studies. He then regressed the coefficient estimates of all the studies on study characteristics. Characteristics included, amongst others, where the study took place, and whether it was a traditional or modern environment. Results supported those of Lockheed et al. (1980). There were higher returns to education in modernizing environments as well as higher returns for Asian countries. There were, however, no new studies added for Africa. Surveying the existing evidence for Africa, Appleton and Balihuta (1996) found that effects were mostly statistically insignificant, although they were often large.

Asadullah and Rahman (2009) estimated the effect of schooling on rice production in rural Bangladesh. Using OLS they found positive effects for the household head's education, but after adding in the highest education level in the household, the effect of the head's education became statistically insignificant while the effect of the highest level of education became significant. Estimating the effects with SPF it was found that education was positively correlated with potential output if included in the estimation of the frontier. When education was excluded from the first stage and used as an explanatory variable to measure the sources of inefficiency in the second stage, it was found that education was correlated with reductions in inefficiency, again in the same pattern as the other models.

Appleton and Balihuta (1996) estimated the returns to education for farmers in Uganda using production functions and found positive results. Compared to farmers with no education, four years of education was associated with 7% higher output, while full primary education was associated with 13% higher output. For Ethiopia, Weir (1999) found that education did have positive effects on cereal production but only after four years of schooling had been reached. Having four or more years of schooling increased production by more than 10% compared to no schooling when using OLS.

For northern Nigeria, Alene and Manyong (2007) found significant positive effects for schooling, but only when farmers were using new technologies. They found no effect for those working with traditional technologies. The authors used a switching regression model to model a two-stage process where in the first stage, farmers can choose to adopt better cowpea varieties or not, and in the second stage cowpea production is modelled given adoption or not. Whether the household head had four or more years of education had a positive significant effect on the adoption of better technologies and it also had a positive effect on cowpea production given that they adopted new technologies. Having four years of education increased cowpea production by 25.6%, if they used improved cowpea varieties. The proportion of other household members who had completed primary schooling had no significant relationship with adoption of better varieties or production.

Jamison and Moock (1984) estimated the returns to education in Nepal using OLS and included controls for cognitive ability and family background with the aim of accounting for the endogeneity of education. Measures of cognitive ability were results on a numeracy test, Raven's Progressive Matrices Score (which is a measure of reasoning ability) and a score for agricultural knowledge. Measures of family background were father's landholding size and literacy. They found that education did not have a significant effect on rice production but it did have a significant effect on wheat production. Having at least 7 years of education was associated with 31.1% increase in wheat production on average without controlling for cognitive skills and family background and 27.1% on average when controlling for those factors. Amongst cognitive skills and family background, only numeracy had a significant effect on wheat production. Being in a region that had contact with agricultural extension services also had a significant effect on wheat production.

A few studies have also distinguished between the allocative and worker effect of education. Appleton and Balihuta (1996) estimated the effect of education on aggregate production without controlling for capital and other purchased inputs and found evidence for the allocative effect of education. Four years of schooling (when compared to no schooling) was associated with 7% higher production when capital and purchased inputs were controlled for, and 10% higher production when those variables were not controlled for. Weir (1999) only found weak evidence that there was a small (1%) allocative effect on Ethiopian cereal crop production for education of non-farming household members. Ram and Singh (1988) studied education's allocative effects on data in Burkina Faso. They found that for household heads, education had a large allocative effect and small worker effect, while for other household members, education had a large worker effect and small allocative effect.

Earlier, the role of education in the adoption and dissemination of new technologies in communities was discussed, but researchers have also tested more directly whether there are community level effects. This has usually been done by adding controls to production functions which capture the effects of the education of farmers in close proximity to the respondents. Asadullah and Rahman (2009) controlled for neighbours' education in their production functions but failed to find positive effects. Appleton and Balihuta (1996) used the average years of education of other farmers in the enumeration area (EA) of the farmer. They controlled separately for the average years of primary and secondary education and found positive results for primary but not for secondary education. An extra year of average primary schooling in the EA was associated on average with a 4% increase in crop production for farmers.

Davis et al. (2010) discuss another form of education which does seem to have positive effects in Africa - Farmer Field Schools (FFS). FFS are aimed at adults and usually work with farmers meeting once per week informally with a facilitator. Through experiential learning, farmers then learn new techniques, how to solve problems, and they are assisted with decision making. The authors used a number of methods to estimate the effects of FFS on farmers in Tanzania, Uganda, and Kenya. FFS were found to increase crop yields by 80% in Kenya, and 23% in Tanzania, while no significant effects were noted in Uganda, which the authors note might be because another government development plan was also running in the same areas as FFS.

The general picture that has emerged so far is that education does have a positive relationship with production in modernizing agricultural settings, but the effects are small. The effects do seem to be heterogeneous, however, and increase with the use of better technologies. Furthermore, education leads to earlier adoption of new technologies. The current literature has, however, not yet sufficiently dealt with the endogenous nature of education when estimating returns in agricultural productivity. The most well known source of endogeneity is individual ability. Another is the fact that educational attainment can be a function of farm productivity because households with more productive farms have more income to pay for education. Foster and Rosenzweig (2004) showed that in India, during the green revolution, increases in agricultural productivity, due to technical change, were associated with increases in school enrollment. Jamison and Moock (1984) attempted to establish causality by controlling for measures of ability and family background but there is no reason to believe that they controlled for all endogenous factors and that their measures of ability and family background sufficiently cover those two sources of endogeneity. Without an experimental or quasi-experimental estimation technique, questions around endogeneity will remain.

3 Background on Malawi

To contextualize the analysis, this section provides a brief background of the Malawian economy and education system. This is followed by a review of previous studies on the returns to education in the country.

3.1 Economy

Malawi is a landlocked country in Sub-Saharan Africa that shares borders with Mozambique, Zambia, and Tanzania. The country is rated as a low-income country by the World Bank (2015). Poverty levels are high. Using the $1.25 and $2 per day poverty lines, headcount poverty rates for 2010 were 72% and 88% respectively (World Bank, 2015). At the national poverty line (37 002 Malawian Kwacha per year) the headcount poverty rate in 2010 was 50.7% nationally, 17.3% for urban areas, and 56.6% for rural areas (NSO, 2012a). Evidently, poverty is more concentrated in the rural areas where the majority of the population are subsistence farmers.

Agriculture, forestry, and fishing is the largest sector in the country. It has contributed between 30-35% of GDP since 2011 (Reserve Bank of Malawi, 2014). The agricultural sector can be divided into two sub-sectors - household and estate agriculture. Household agriculture contributes more than 70% to the sector while estate agriculture contributes the rest.

Malawi's staple food is maize and it dominates both consumption and agricultural production. Maize is planted in October/November and harvested in April/May. Rain is of vital importance to the crop because the extent of irrigation is negligible. The cycle coincides with the rainy season in the country which stretches from January to March (Zant, 2012).

The main cash crop in Malawi is tobacco and specifically burley tobacco which has been named "green gold" because of its profitability (Orr, 2000). Other important crops in the country are sugarcane, tea, coffee, wheat, rice, groundnuts, pulses and cotton. The main export crops are tobacco, sugarcane and tea with the latter two being produced mostly (more than 85%) by commercial estates (Chirwa et al., 2008).[4]

Malawi introduced a large-scale farm input subsidy program (FISP) in the 2005/2006 cropping season. The program aimed to supply 50% of farmers with subsidized fertilizer for maize, and also provided vouchers for modern maize seeds and tobacco fertilizer (Dorward and Chirwa, 2011). The official aims of the program were to increase the production of maize, promote food security at household level and to increase incomes in rural areas. Whether the program has been successful is uncertain (Lunduka et al., 2013).[5]

Unemployment in Malawi is low because most individuals desperately needing employment can revert to the informal sector and do casual work. This type of work is commonly referred to as "ganyu" work. Many individuals engage in this type of labour as a coping strategy to deal with food insecurity (Bryceson, 2006). Whiteside (2000) argues that it is the most significant source of income after own agriculture for rural households. Whiteside (2000) further notes that ganyu labour and household production can be in conflict from time to time as ganyu can lock households in cycles where immediate food shortages are addressed but long term food supply is not. This then creates the need to do more ganyu work. The problem is exacerbated by low ganyu wage rates.

3.2 Education

Educational attainment in Malawi is very low. The government introduced universal FPE in the 1994/95 school year. Some cohorts also started receiving FPE earlier. FPE was introduced in the 1991/92 school year for standard 1 with the idea that every cohort after that would receive FPE as well. Together with that government programme, the United States Agency for International Development (USAID) introduced a programme in 1992/93 to abolish school fees for all girls in Standards 2-8 who had not repeated (Kadzamira and Rose, 2001). Table 1 shows which learners received FPE between 1991/92 and 1994/95.

[4] An estate monopoly on burley tobacco was ended in 1990 which allowed subsistence farmers to plant it (Orr, 2000).

[5] See Lunduka et al. (2013) for a review of the evidence of the program.

Table 1: Cohorts that received Free Primary Education

		Standard															
		Std. 1		Std. 2		Std. 3		Std. 4		Std. 5		Std. 6		Std. 7		Std. 8	
		M	*F*	*M*	*F*	*M*	*F*	*M*	*F*	*M*	*F*	*M*	*F*	*M*	*F*	*M*	*F*
Year	1991/92	Y	Y	N	N	N	N	N	N	N	N	N	N	N	N	N	N
	1992/93	Y	Y	Y	Y	N	Y*	N	Y*	N	Y*	N	Y*	N	Y*	N	Y*
	1993/94	Y	Y	Y	Y	Y	Y	N	Y*	N	Y*	N	Y*	N	Y*	N	Y*
	1994/95	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y

Source: Kadzamira and Rose (2001)
M and F refers to males and females respectively. Y and N refer to yes and no respectively on whether cohorts received FPE or not. Y* indicates that only non-repeating girls received FPE.

There is no doubt that the programmes helped increase enrolment, which makes the use of FPE as an instrumental variable relevant. It did, however, put large financial strains on Malawi's education system and consequentially education was not supplied at an acceptable level of quality while it also squeezed resources in other parts of the education system (Kadzamira and Rose, 2003).

With agriculture being the dominant sector in the poor parts of the country, measures to improve agricultural productivity are clearly needed. One channel that provides opportunities for this is education. Introducing FPE is an obvious large expense to a poor country and for that reason measuring whether it has had positive effects on agricultural productivity in Malawi is important.

3.3 Evidence on the Returns to Education in Malawi

The effect of education on agriculture in Malawi has not been studied extensively. Chirwa (2005) studied factors that were associated with the adoption of improved technologies – inorganic fertiliser and hybrid seeds. This was estimated using bivariate probit regressions to account for the fact that the decisions to adopt either or both of the technologies might be related. Education was found to be a positive and strongly significant factor in the decision to adopt inorganic fertilizer. It was positively but not significantly associated with the adoption of hybrid seeds. Chirwa (2005) noted that the findings were in contrast to those of Zeller et al. (1998) who did not find a significant effect for education in the adoption of new technologies.

Matita and Chirwa (2009) estimated the returns to education for agricultural activities using data from the Second Integrated Household Survey (IHS2). They estimated OLS models of maize output, tobacco sales, business profits, and household income. For maize output they included an explanatory variable which is presumed to be education of household head.[6] Returns were positive and significant and were estimated at 3.91% per year. Households where the head had completed primary schooling produced 9.85% more than households where the head had no schooling. Similarly, heads with junior secondary schooling produced 17.54% more, senior secondary schooling produced 41.56% more and technical and university graduates produced 77% more than the unschooled. For tobacco earnings, a year of education was associated with a 5.63% increase in earnings. Returns to schooling categories (with no education as the base) were as follows: primary schooling (24.45%), junior secondary schooling (32.44%), senior secondary schooling (53.37%), technical education (150%), and a university degree (160%).

Kassie et al. (2014) studied poverty and its determinants for a small sample of rural maize farmers. They randomly sampled 68 households from the Balaka district and 87 households from the Mangochi district. The two districts were randomly selected but had to adhere to the requirement that they only had a 20-40% probability of having a failed season. This was done to make the districts more comparable with each other by limiting the role that climatic factors could have on the harvests of farmers. They used quantile regressions with per adult equivalent expenditure divided by the poverty line (using the $1.25 per day poverty line) as a dependent variable to estimate the determinants of poverty. They included both a variable indicating whether the household head was illiterate and also the average level of education in the household. Both where found not to be significantly correlated with well-being.

There have also not been many studies on the returns to investment in education in the modern wages sector of the economy. Mingat et al. (1985) used data from the 1981 Household Income and Expenditure Survey, supplemented with civil servants earnings data for 1983, and the 1983 Education Finance Study. They found that compared to anything less than primary schooling, the private rates of returns to primary education were between 11.6% and 15.7% depending on their assumptions. Further, the private rates of return were 26.3% for lower secondary schooling, 16.8% for upper secondary schooling, and 46.6% for university graduates. The social returns were marginally lower but had the same pattern as the private returns except for university, for which the social returns were 11.5%.

Chirwa and Zgovu (2001) used survey data on paid employees from four rural districts to study the determinants between choosing to work casually or formally and whether the returns to education differed between the two sectors. Using Mincerian earnings functions they estimated

[6] It is not totally clear whether household head's education was used, but Matita and Chirwa (2009, 7) state that their main hypothesis is that the education of a household head is positively correlated with maize production.

the average return to an extra year of education to be 6.61% with OLS on the full sample. They also modelled the two sectors separately using OLS and also the Heckman (1979) selection model to control for selection bias. Returns to education in the formal sector were estimated to be 9.44% using OLS and 9.41% using the Heckman estimator. For casual employment, returns were estimated to be 4% but insignificant using OLS, and 5.41% and significant at a 90% confidence level using the Heckman method. Yet samples were small. The authors argued that the results showed that when informal sectors are excluded from estimations in rural economies, the returns to education tend to be overstated.

Chirwa and Matita (2009) used data from the Second Integrated Household survey (IHS2) for 2004/05 to estimate the returns to education. They estimated Mincerian type earnings equations for employed individuals using OLS. The authors noted that due to data limitations, corrections for bias were not possible. They found that education had a significant positive effect on earnings. An extra year of education was associated with a 10.12% increase in earnings on average.

4 Data and Methodology

4.1 Data

This study uses the Third Integrated Household Survey (IHS3) from Malawi. The survey was conducted in 2010/2011 and forms part of a wider range of surveys conducted by the World Bank as part of the Living Standards and Measurement Study (LSMS) as well as the Living Standard and Measurement Study – Integrated Surveys on Agriculture (LSMS-ISA). The IHS3 data contains household, community level, fisheries, and agriculture components. The household and agricultural components of IHS3 are used in this study. The household questionnaire contains detailed information at the individual and household levels, while the agricultural questionnaire was conducted at plot level. IHS3 surveyed 12 271 households and 10 401 households also answered the agricultural questionnaire (NSO, 2012b).

To show the importance of household agriculture in the country, Table 2 shows the distribution of employment over different sectors in IHS3 for the working-age population. Some individuals working in other sectors may also own farms. It is also the case that individuals working in the private sector could be employed on commercial agricultural estates. These individuals are not included under household agriculture as that was not the main sector of employment they reported. Around 55% of the employed work in household agriculture. If ganyu workers, who mostly reside in rural areas, are counted with the household agricultural workers, around 71% of the employed work in smallholder agriculture. Given that individuals mainly employed in other sectors could also possibly manage agricultural plots, the extent of employment in agriculture is possibly understated.

Table 2: Employment Distribution by Sector

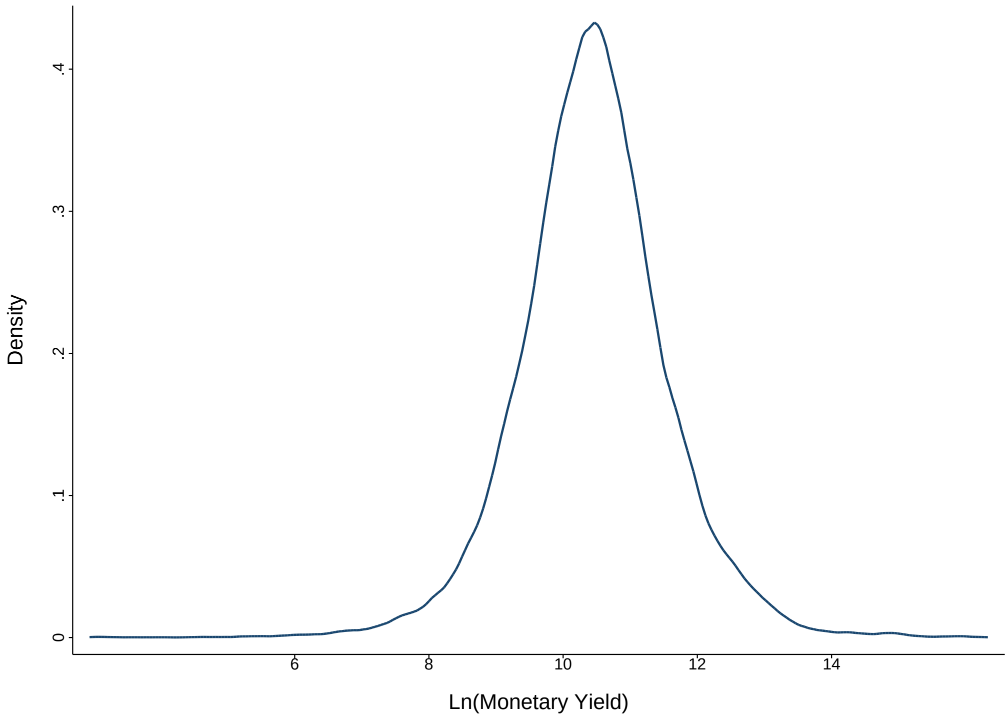
	%	Cum. %
Private	11.6	11.6
Public	3.9	15.6
NGO/Church	1.1	16.6
Self Employed	12.0	28.7
Ganyu	16.8	45.5
Household Agriculture	54.5	100.0

Source: Own Calculations using Malawi's Third Integrated Household Survey, 2010/2011.
Sample is limited to the working-age population which is age $\geq$ 15 & age $\leq$ 64.

Next, the data used for the subsequent analysis is discussed. The variables used loosely follow Kilic et al. (2015), who studied gender productivity differentials in smallholder agriculture in Malawi. The data is captured in a manner that households can farm numerous plots. Plots could be managed by the same or different household members. Plot level data also complicates the estimation procedure. If, for example, the number of plots owned by a household is correlated with education, it will inflate the estimates on education if education has a positive correlation with production. To deal with this, this study takes the probability weight of each individual and divides it by the number of plots he/she manages. Running IV estimates at individual level (instead of plot level) and weighting the estimates using individual probability weights produced similar results.

One concern in the agricultural data was the units of measurement in which harvests were reported. For example, farmers could report harvesting in kilograms, or a number of other non-standard measuring units (such as an ox-cart). The amount of other commodities harvested, such as ground nuts, could also be reported as shelled or unshelled. Harvests were converted back to kilograms using conversion factors which were obtained from researchers for LSMS-ISA. Estimates for the total value of production were then calculated using the median kilogram price in each enumeration area if there were at least 10 observations. If not, the median was taken for the next level of geographical aggregation, which is the traditional authority, followed by district, region and then country. To deal with outliers, OLS regressions on logged yield were estimated using the most exhaustive model specification (discussed later). From this the studentized residuals for the estimates were obtained, and observations with studentized residuals larger than 5 or smaller than -5 were dropped. Figure 1 shows the distribution of the logged estimated monetary yields - defined as the total value of all produce divided by land size in hectares. The distribution is fairly smooth and approaches the shape of a normal distribution.

Figure 1: Distribution of ln(Agricultural Yields (Kwachas))



Source: Own Calculations using Malawi's Third Integrated Household Survey, 2010/2011.

Two indices to control for wealth were also created using the household level data. The first is a farm implements index: because it is created at the household level (as opposed to plot level), it implies potential access to implements. The second is a wealth index that is constructed from whether households own a range of durable goods. Both indices are created using principal components analysis (see Filmer and Pritchett (2001) for example).

Table 3 gives a description of the agricultural data used in the regression analysis. This data is based on the sample of working-age population farm managers for which none of the data was missing, which was 14293 plots. The average years of education of plot managers is 5.24 years which represents incomplete primary education. 27% of plots are managed by females while the average age of plot managers is 38.18 years. Approximately 14% of plot managers are also employed in the formal sector. Furthermore, the average household size for plot managers was 4.89 and the average child dependency ratio in the households was 1.13. The average size of plots was 0.5 hectares while the average monetary yield was 50295.86 Kwachas. In terms of labour, female household members, on average, worked more on plots than male members while hired and unpaid labour was not used much in general.

Table 3: Agriculture Data Description - Plot Level

	Mean	Median	Min	Max
Yield per Ha (Kwachas)	64576.14	30888.13	18.97	12355250
Used Pesticides/Herbicides (Yes=1 No=0)	0.01	0.00	0.00	1
Used Fertilizer - Organic (Yes=1 No=0)	0.12	0.00	0.00	1
Used Fertilizer - Inorganic (Yes=1 No=0)	0.66	1.00	0.00	1
Fertlizer Inorganic (Kg per Ha)	195.68	102.96	0.00	51480
HH Labour - Males (hrs per Ha)	467.16	296.53	0.00	30023
HH Labour - Females (hrs per Ha)	548.87	360.07	0.00	34348
HH Labour - Children (hrs per Ha)	88.05	0.00	0.00	27676
Hired Labour (Days per Ha)	7.01	0.00	0.00	3459
Free Labour (Days per Ha)	0.94	0.00	0.00	1483
Plotsize (Ha)	0.51	0.33	0.00	295
HH Agri implements index	0.11	-0.17	-2.21	29
HH Durable Goods index	-0.54	-1.13	-1.54	20
Season[b]	0.58	1.00	0.00	1
Household size	4.90	5.00	1.00	17
Education (yrs)	5.24	5.00	0.00	15
Female	0.27	0.00	0.00	1
Married	0.79	1.00	0.00	1
Age	38.21	36.00	15.00	64
Household size	4.90	5.00	1.00	17
Child dependency ratio	1.13	1.00	0.00	8
Formally Employed	0.14	0.00	0.00	1

Source: Own Calculations using Malawi's Third Integrated Household Survey, 2010-2011.
Sample is limited to the working-age population which is age ≥ 15 & age ≤ 64.
[b] Season is a dummy variable where 0 indicates the 2008/2009 rainy season and 1 indicates the 2009/2010 rainy season.

Apart from inorganic fertilizer, the use of modern technologies was very low. Herbicides and pesticides were used on 1% of plots. To further highlight the low use of technologies, Table 4 shows the percentage of plots which had access to different farm implements. Less than 1% of plots had access to tractors, 1.65% had access to an ox-plough and the percentage of plots having access to a ridger, treadle pump and sprayer were 0.66%, 2.69% and 4% respectively. On the contrary, almost all plots had access to a hand hoe. Less than 1% of plots had irrigation systems while 29.29% had access to a watering can.

Table 4: Percentage of Plots using a given Agricultural Technology

	%
Hand Hoe	99.65
Sprayer	3.92
Treadle Pump	2.70
Watering Can	29.27
Ox Plough	1.66
Tractor	0.04
Ridger	0.66
Irrigation	0.54

Source: Own Calculations using Malawi's Third Integrated Household Survey, 2010/2011.

For the formal sector in Malawi, wages are reported on the main jobs individuals had in the last 12 months. Only the wages of those who were still employed in the formal sector at the time of their interview were considered. Similarly, the sample is limited to the working-age population and only those individuals for which there were no missing values. Outliers are once again determined by running OLS regressions on logged earnings using the most exhaustive model specification (discussed later) and removing observations with studentized residuals above 5 or below -5. Table 5 provides a description of the data for formal sector employees that is used for the estimates of earnings regressions. Formal sector employees generally live in houses with fewer people and lower child dependency ratios than agricultural plot managers, while they also have higher levels of education with 8.42 years of education on average. Figure 2 show the distribution of formal sector sector wages.

Table 5: Wage Data Description

	Mean	Median	Min	Max
Education (yrs)	8.46	9.00	0.00	15.00
Earnings^{+}	17822.21	8000.00	173.58	900000.00
Female	0.20	0.00	0.00	1.00
Married	0.77	1.00	0.00	1.00
Age	35.03	33.00	15.00	64.00
Rural	0.59	1.00	0.00	1.00
Household size	4.81	5.00	1.00	18.00
Child dependency ratio	0.85	0.67	0.00	5.00

Source: Own Calculations using Malawi's Third Integrated Household Survey, 2010/2011.
$^{+}$Earnings are displayed as monthly Malawian Kwachas earned.

4.2 Methodology

4.2.1 Instrumental Variables

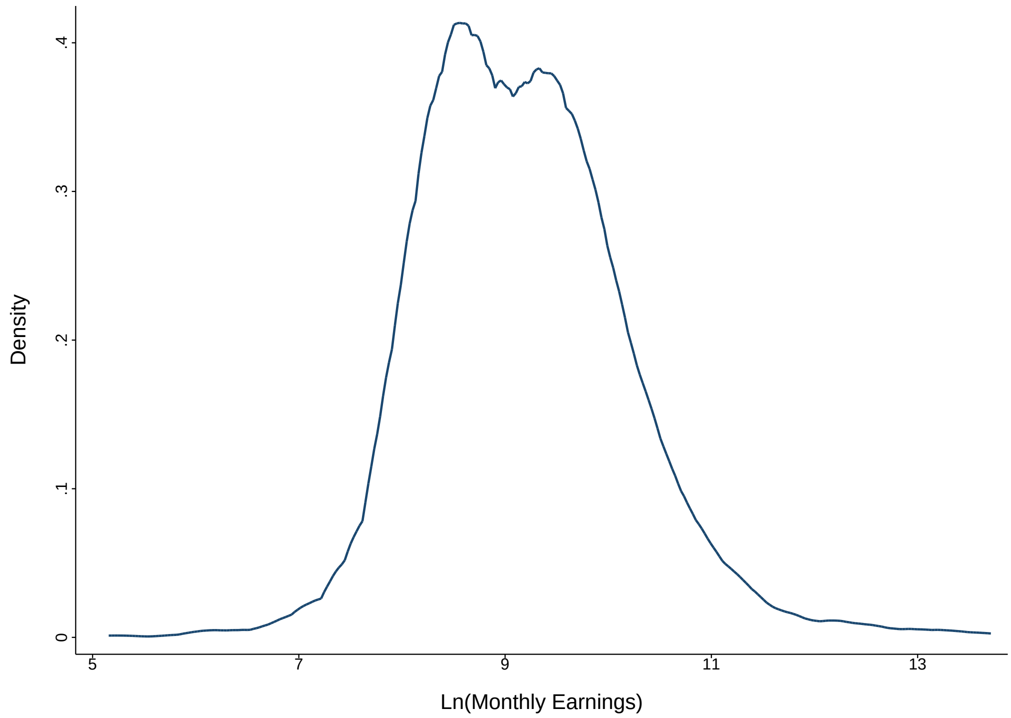
A two-staged least squares (2SLS) approach is used to estimate the causal effect of education on production. The following model is estimated:

$$S_i = X_i\beta + Z_i\gamma + \mu_i \tag{5}$$

$$Y_i = X_i\beta + S_i\alpha + \varepsilon_i \tag{6}$$

where X_i is a vector of control variables for individual i , Z_i is a vector of instrumental variables, S_i is the years of schooling, Y_i is either the log of earnings or the log of yields, and μ_i and ε_i are the error terms that are assumed to be $N\left(0, \sigma^2\right)$ distributed.

Figure 2: Distribution of ln(Monthly Earnings (Kwachas))



Source: Own Calculations using Malawi's Third Integrated Household Survey, 2010/2011.

Cobb-Douglas type production functions are used to model agricultural yields. The log of monetary yield is regressed on numerous inputs into the production process. Inputs into the production process include land, household and other labour, the use of fertilizer, pesticides, herbicides and capital. Capital is proxied by the two created indices for durable goods and access to farm implements.

In terms of land, it is expected that there are decreasing economies of scale. This is known as the inverse production hypothesis. The hypothesis states that crop yields - defined as the amount of crop produced per unit of land - decrease as land size increases. Larson et al. (2014) found a significant correlation of -0.349 between the log of land and the log of yields in Malawi using OLS.

To account for rainfall and other climatic factors, districts, elevation, agro-ecological zones, and season of harvest are controlled for using geographic variables from the IHS data. Apart from education, other individual characteristics that are controlled for include age, whether plot managers are married, and, gender.

With regards to gender it is expected that the coefficient on being female would be negative. Female farmers are less productive than male farmers. Female farmers have been shown to have worse access to resources and are less productive than male farmers with the resources at their disposal (Kilic et al., 2015; Oseni et al., 2015).

Depending on whether inputs are included in the model will lead to the estimation of different effects of education. Provision for the worker and allocative effect is made. When the effect of education on the total value of production is estimated while controlling for other inputs, the worker effect is estimated. Not controlling for other inputs will estimate the worker plus allocative effect. A Wald test is also done to estimate whether the coefficient on education differs significantly between the worker and allocative effect models. The null-hypothesis of the test is that the coefficients do not differ significantly from each other.

For comparison, the returns to education on the earnings of the formally employed are also estimated. This will show whether returns to education are heterogeneous across sectors. For the earnings estimates, OLS and IV models will be estimated. In the estimates, the log of monthly earnings (including monthly profits) is the dependent variable. Years of education is the independent variable of interest. The models also control for age and its square, individuals' gender and marital status, where individuals live, and sector of employment.

4.3 Instrumental Variables for Education

Two different instrumental variables will be used for education. The first is the introduction of Free Primary Education and the second will be the age of paternal orpanhood. The first is formed by exploiting a change in the cost of primary schooling. Between 1991 and 1994 FPE was introduced in Malawi. This shock is expected to have increased the demand for schooling which would have led to an increase in enrolment in primary schooling. A variable capturing whether individuals benefited from this policy change or not should thus be correlated with the amount of schooling received but not directly with either earnings or agricultural productivity.

The IV created to capture the effects of FPE was designed as follows. Firstly, children could get FPE whether they used it or not. This implies that cohorts of school going age (6 years) in 1991/92 and subsequent years get the treatment. Secondly, students who started school in 1991/92 or later regardless of their age also received the treatment. Finally, students who were already in higher grades in 1991/92 who potentially received some FPE due to the introduction for non-repeating girls in 1992/93 or full introduction in 1994/95, also received the treatment.

This was inferred by calculating in which grade they were when FPE was introduced by subtracting their years of education from the year that they stopped school. This relies on the assumption that those students did not repeat grades during their tenure in school. Thus, anyone who could have or did receive FPE, and students who possibly received some years of FPE, were given a 1 and the rest a 0. For the regression analysis, the proportion of individuals who received partial or full FPE was approximately 23% and 30% in the agricultural and formal sectors respectively.

The second instrument that will be used is people's age when their father died. Parental death should thus be correlated with educational attainment and should not be directly correlated with productivity or earnings in the long term. Many studies find negative effects of parental death on schooling. Using Demographic and Health Survey (DHS) data for 10 countries in Southern Africa, Case et al. (2004) found that orphans were significantly less likely to go to school than non-orphans in the same households. The authors also estimated that for Malawi in 1992, 9.2% of children aged 14 and younger had lost either one or both of their parents, while in 2000 that rate was 11.7%. For the same age group, the rate of paternal orphanhood was 4.6% in 1992 and 6.5% in 2000, while for maternal orphanhood the rate was 3.0% in 1992 and 2.9% in 2000. Further, they found regressions for school enrolment in Malawi indicated that orphans were significantly less likely to be enrolled in school compared to non-orphans for the same demographic profile. The negative effects were smaller in 2000 than in 1992, and for double and paternal orphans, effects were not significantly different from 0 in 2000. This possibly indicates that FPE reduced the effects of the shock. For both years the negative effects of maternal orphanhood were greater than paternal orphanhood.

Evans and Miguel (2007), using a 5-year Kenyan panel dataset, also found a significant decrease in school participation after the death of a parent. The effect was larger for the death of mothers and also for children who had low academic performance prior to a parent's death. Both paternal and maternal orphanhood were tested as instruments in this study, but paternal orphanhood was a much stronger instrument than maternal orphanhood. This is not a common finding, however, Alam (2015) also found that paternal illness (as opposed to death) had significant effects on schooling outcomes while maternal illness did not, for both boys and girls. In both the agricultural and formal sector estimation samples, aproximately 33% of individuals lost their father before the age of 25.

Both instruments have potential reasons for being endogenous and these caveats will be taken into account in the discussion of the results. FPE could have reduced the quality of schooling by putting strain on the schooling system. Research from both Kenya (Lucas and Mbiti (2012)) and Tanzania (Valente (2015)) on the introduction of FPE notes negligible declines on test scores though. Similarly it could be argued that government spending on public education could lead to crowding out of expenditure on goods that could affect agricultural productivity. It is questionable though, how the introduction would affect smallholder farmers 15 years later. Previously, Uwaifo Oyelere (2010) has also used the length of exposure to FPE in Nigeria as instrument in measuring the returns to education.

Paternal orphanhood could be causally correlated with production if, for example, poorer fathers are at greater risk of mortality, which could be correlated with their children's production. Yet one can control for own wealth in production functions. This control would be valid if it is assumed that fathers' and their children's wealth are highly correlated. Secondly, it might affect the motivation of individuals in the short and long term. However in which direction the motivation will go is not clear. Individuals could for example become less motivated to farm given grief, or could become more motivated to succeed and provide for the future given that their father has passed away.

The variable for the age at which parents died was truncated at a value of 25. This value was given to all individuals older than 25 whose parents had not yet died. This assisted in dealing with missing values on parental death, as well as classifying those whose parents died at a later age. Death at any later age should not influence educational attainment. Possibly a few candidates would still be in tertiary education at or after the age of 25. They are, however, few and are not expected to influence the results substantially. Rigobon and Stoker (2005) showed that truncated instrumental variables do not bias estimates in general. Specifically, if an uncensored version of the variable is observed and it is a valid instrument, it still produces a valid instrument.

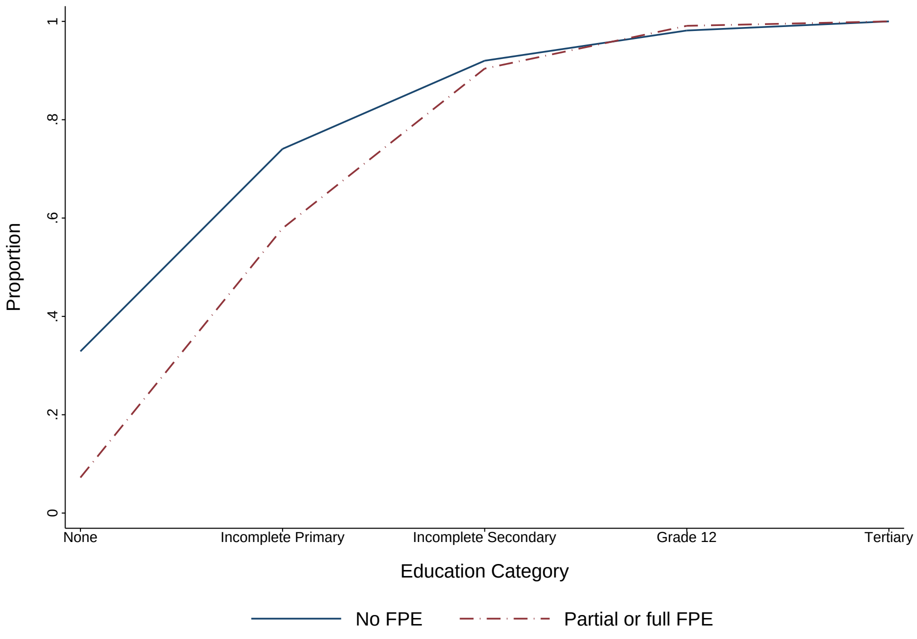
Angrist and Imbens (1995) show that where IV's have variable treatment intensity 2SLS estimates can be interpreted as an Average Causal Response (ACR). This is a weighted average of the effect of the endogenous variable on the outcome for those whose behaviour was altered because of the exogenous treatment effect, if two assumptions are satisfied. This paper will refer to the ACR as a local average treatment effect (LATE). The first is that the instruments only affect the outcome variable through the instrumented variable. The argument for the validity of the instruments was already made earlier. The second assumption is monotonicity, which implies that the different levels of treatment affect individuals in the same direction when compared to not receiving the treatment. In this example it means that receiving any FPE always increases educational attainment compared to individuals who received no FPE. For the age of paternal death it implies that education is always positively correlated with the age of paternal orphanhood.

Angrist and Imbens (1995) note that it is possible to get an idea about whether the monotonicity assumption holds by looking at whether cumulative distribution functions (CDF) of education at some level of treatment and at no treatment cross. To do this the CDF of education is estimated for different treatment groups. CDF in this case will show the proportion of individuals in the sample who have completed a certain level or less of education.

With regards to FPE a person falls either in the treatment or no treatment group. For age of paternal orphanhood individuals are categorised by different stages of school when they became orphans: before school ($age < 6$), during primary school ($6 <= age <= 14$), during secondary school ($15 <= age <= 18$), and after secondary school ($age > 18$). Figure 3 shows the CDF of education for those who received no FPE and those who received FPE. Figure 4 shows the CDF of education by different age groups when paternal orphanhood started. It is evident that FPE positively influenced the distribution of education and that the CDF lines do not cross until after primary schooling. Given that the effect of the policy should be noticeable on primary schooling, the figure suggests that the monotonicity assumption holds with regards to FPE. For the age of paternal orphanhood, the monotonicity assumption also holds. Individuals whose fathers are still alive or died after school are taken as those who received no treatment because, for them, there is no effect of paternal orphanhood on schooling outcomes. None of the CDFs for groups of individuals whose father died earlier cross with the CDF for those whose father did not die during their school going age. All of the other CDFs also lie to the left which means that paternal orphanhood during schooling appears to have had negative effects on educational attainment.

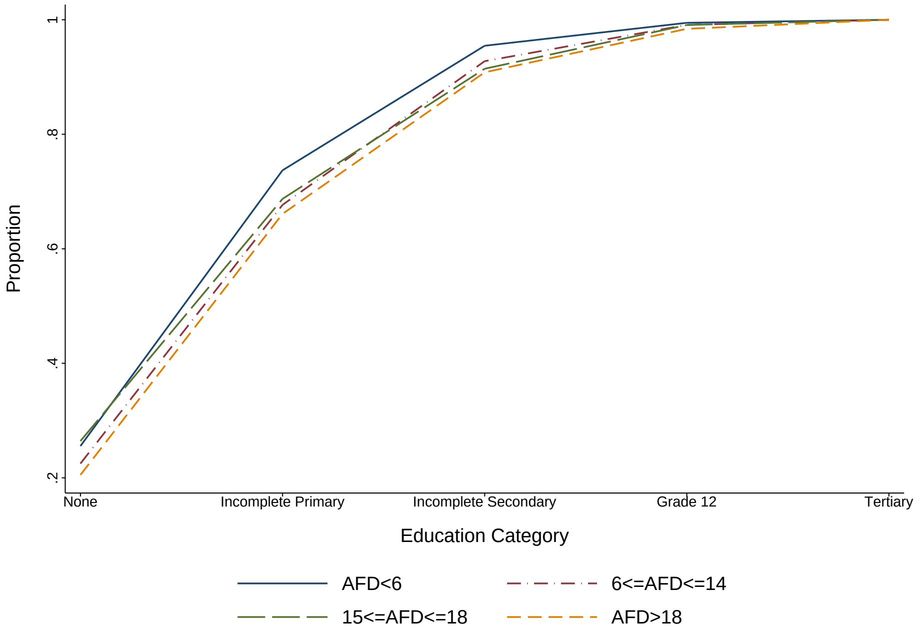
To illustrate the effects of the two instruments in more detail, differences between the CDFs of those that received no treatment and those who received certain levels of treatment are also shown. Firstly, grouping was done between those that received no FPE and those that received partial or full FPE. Within these two groups, sub-groups were identified by age of paternal orphanhood as discussed aboved. For each of these sub-groups the reference group was taken as those whose father did not die while they were at school. For example, the CDF of individuals who received no FPE and whose father died when they were younger than 6 years old is subtracted from the CDF of those who also received no FPE and whose father was still alive by the time that they were 19 years old. Similarly, the CDF of individuals whose father

Figure 3: Cumulative Distribution Functions of Education for Individuals who Received No FPE and Those that Received at Least Partial FPE



Source: Own Calculations using Malawi's Third Integrated Household Survey, 2010/2011. AFD refers to age at which father died.

Figure 4: Cumulative Distribution Functions for Education for Different Age Groups of Paternal Orphanhood

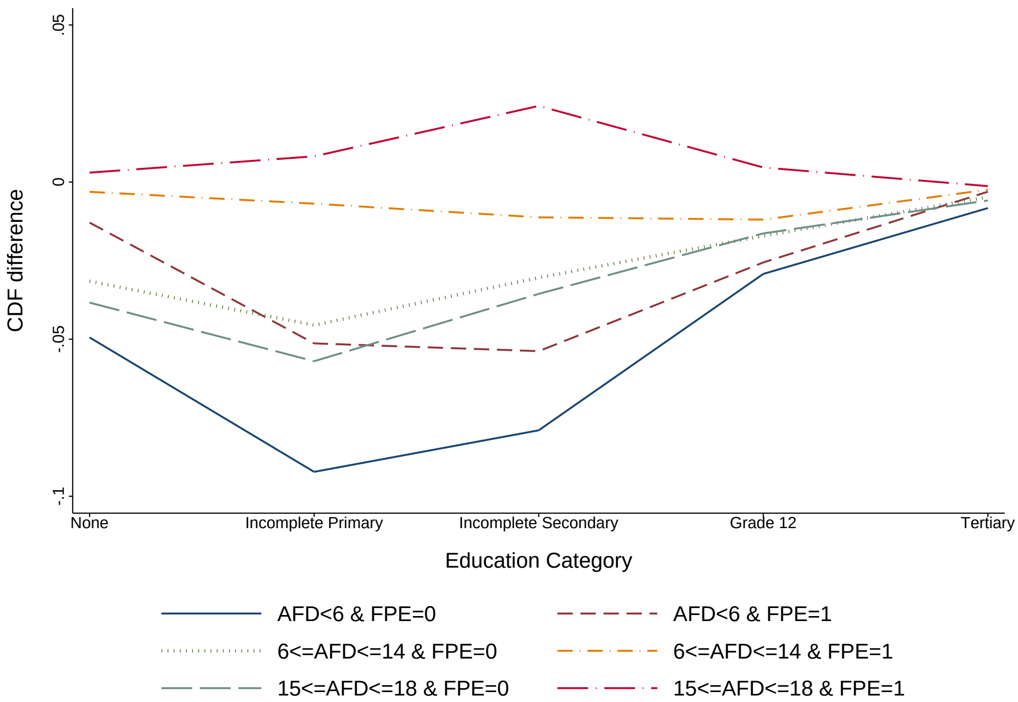


Source: Own Calculations using Malawi's Third Integrated Household Survey, 2010/2011. AFD refers to age at which father died.

died when they were younger the 6 years old and who did receive FPE, is subtracted from the CDF of those whose father was still alive by the time that they were 19 and who received FPE. Figure 5 shows the differences.

From figure 5 it is generally clear that paternal orphanhood during or before school negatively affects schooling outcomes. It is also evident that the negative effects of paternal orphanhood are much less severe when individuals received FPE. This supports the suggestion that paternal orphanhood negatively affects education through an income shock.

Figure 5: IV distributional Shocks



Source: Own Calculations using Malawi's Third Integrated Household Survey, 2010/2011.

For the respective IV's the LATE measures the effect of education on those individuals whose behaviour was altered because of FPE or paternal orphanhood. With regards to FPE, this implies that the estimate captures the effect of education for those who would never have attended school or who would have dropped out earlier if primary schooling were not free. With regards to the estimates using age of paternal orphanhood as treatment, the estimates are measuring the effects of education on those who - because of paternal orphanhood - could not go to school or had to drop out. Both represent the imposition of, or relief from, a credit constraint. FPE offered a credit relief to individuals who could not have gone to school otherwise. Paternal orphanhood imposed a credit constraint on those who had to stop schooling.

If it is assumed that credit constraints affect both groups equally, an alternative explanation would be that the instruments identify two groups with different expected returns to schooling. Students who only entered school because of FPE, would have been those who would have had low expected returns to education in the counterfactual. If they had to pay, the gains from education would not have been worth the cost. Similarly, students who had to exit the schooling system as a result of an income shock such as paternal orphanhood, would have had high counterfactual returns. They would have been individuals who did see the value of investing in education as they expected that their future returns (due to education) would be greater than the cost of the investment in education. It is expected that if this explanation holds truth, returns to education would be higher when age of paternal orphanhood is used as IV.

This paper does not address the possibility of non-linear returns to education. There could be increasing or decreasing marginal returns to education in agricultural productivity (or the formal sector). If this is the case and the LATE identifies groups that stop schooling at systematically different levels, returns could be inflated for subgroups identified by the respective instruments.

5 Results

As it was established in the literature review, there is not strong empirical support for the case that education has a significant influence on agricultural productivity. To establish that the IV's work as expected, the results for the returns to education in the formal sector are discussed first as it is generally accepted that there are significant returns to education in the formal economy.

To test whether the instruments are weak, the value of the first stage F-statistic of the instrumental variables is shown as proposed by Bound et al. (1995). The rule of thumb proposed by Staiger and Stock (1997) is that instruments are not weak if the F-statistic is above 10. The P-value of the Wu-Hausman test is also shown. Under the test, the efficient OLS estimate is compared to the consistent IV estimate. Under the null-hypothesis there are no systematic differences in the coefficients of the two models.

The OLS and IV results for the formal sector are shown in Table 6. The OLS estimate of the return to education suggests that an extra year of education is associated with a 11.3% increase in wages on average, controlling for other factors. The FPE IV estimate is insignificant while the paternal orphanhood IV suggests a significant effect of 15.4%.

Table 6: OLS and 2SLS Estimates on ln(Monthly Formal Sector Earnings)

			2SLS Estimates			
			FPE		AFD	
	OLS1	OLS2	1st Stage	2nd Stage	1st Stage	2nd Stage
Education (yrs)	0.141***	0.113***		0.062		0.154***
	(0.009)	(0.007)		(0.038)		(0.046)
FPE			1.315***			
			(0.205)			
Age Father Died					0.057***	
					(0.017)	
Age		0.079***	0.352***	0.089***	0.181***	0.071***
		(0.011)	(0.056)	(0.013)	(0.053)	(0.014)
Age^2		-0.001***	-0.005***	-0.001***	-0.003***	-0.001***
		(0.000)	(0.001)	(0.000)	(0.001)	(0.000)
Sector(ref = Private)		ref.	ref.	ref.	ref.	ref.
Public		0.309***	3.265***	0.479***	3.309***	0.173
		(0.045)	(0.206)	(0.131)	(0.205)	(0.159)
NGO/Church		0.276***	2.537***	0.411***	2.566***	0.168
		(0.093)	(0.328)	(0.141)	(0.335)	(0.152)
Rural		-0.037	-1.390***	-0.108	-1.402***	0.020
		(0.066)	(0.263)	(0.081)	(0.261)	(0.091)
Female		-0.014	-0.244	-0.022	-0.157	-0.007
		(0.045)	(0.248)	(0.047)	(0.261)	(0.046)
Married		0.090**	0.786***	0.133**	0.825***	0.056
		(0.045)	(0.236)	(0.058)	(0.230)	(0.059)
Household size		0.021**	-0.009	0.021**	-0.014	0.022**
		(0.009)	(0.039)	(0.009)	(0.039)	(0.010)
Child dependency ratio		-0.098***	-0.784***	-0.141***	-0.805***	-0.065
		(0.030)	(0.123)	(0.045)	(0.126)	(0.045)
District	No	Yes	Yes	Yes	Yes	Yes
Observations	2985	2985	2985	2985	2985	2985
R^2	0.334	0.454	0.292	0.422	0.286	0.434
F-stat (first stage)			33.596		14.520	
Wu-Hausman p-val				0.084		0.322

Source: Own Calculations using Malawi's Third Integrated Household Survey, 2010/2011.

FPE uses Free Primary education as IV. AFD uses age father died as IV. Significance levels: * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.

Having established that the IV's work and that education can have a significant effect in the formal sector, the agricultural production functions are presented. As a start, OLS regressions are shown in Table 7. The first model shows the correlation between yields and years of education when no other inputs are controlled for. The second model shows the OLS result of the combined allocative and worker effects of education. In this model personal, household, and plot characteristics are controlled for, but inputs are not. The final model also controls for inputs and gives an estimate of the worker effect of education. The difference between model 2 and 3 gives an approximation of the allocative effect of education.

Table 7: OLS Estimates on ln(Agricultural Yields)

	OLS1	OLS2	OLS3
Education (yrs)	0.045***	0.030***	0.010***
	(0.003)	(0.004)	(0.003)
Female		-0.122***	-0.161***
		(0.039)	(0.038)
Age		0.025***	0.024***
		(0.008)	(0.007)
Age^2		-0.000***	-0.000***
		(0.000)	(0.000)
Formally Employed		-0.012	-0.064*
		(0.042)	(0.035)
Season		0.002	0.085***
		(0.031)	(0.028)
Elevation		0.000**	0.000
		(0.000)	(0.000)
Pesticides/Herbicides			0.522***
			(0.097)
Fertilizer - Organic			0.116***
			(0.036)
Fertlizer Inorganic (ln(Kg per Ha))			0.056***
			(0.003)
HH Labour - Males (ln(hrs per Ha))			0.012***
			(0.003)
HH Labour - Females (ln(hrs per Ha))			0.020***
			(0.004)
HH Labour - Children (ln(hrs per Ha))			0.002
			(0.002)
Hired Labour (ln(Days per Ha))			0.024***
			(0.003)
Free Labour (ln(Days per Ha))			0.002
			(0.005)
Land (ln(Ha))			-0.657***
			(0.071)
$Land^2$ (ln(Ha))			-0.023
			(0.021)
Agri implements (access index)			0.083***
			(0.008)
HH Durable Goods index)			0.034***
			(0.007)
District	No	Yes	Yes
Agroecological Zones	No	Yes	Yes
Observations	14567	14567	14567
R^2	0.025	0.090	0.307
Allocative Effect (Wald Test):			
F-Stat			68.318***

Source: Own Calculations using Malawi's Third Integrated Household Survey, 2010/2011.
Significance levels: * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.

The OLS estimates suggest that there is a significant and positive correlation between educational attainment and agricultural productivity. As is expected, the correlation between education and agricultural yields is larger when inputs are not controlled for. This points to an allocative effect of education: it is statistically significant as indicated by the Wald Test. Results suggest that an extra year of education is associated with approximately a 1.0% and

3.0% increase in yields, on average, when inputs are controlled for and when they or not, respectively.[7] In terms of the control variables, the results are generally consistent with what would be expected. Apart from child and free labour which are insignificant, all inputs have a positive and significant correlation with yields, while land size has a significantly negative coefficient, which is consistent with the inverse productivity hypothesis.

The 2SLS estimates are shown in Tables 8 and 9. The instruments all seem to be strong with the first-stage F-statistic well above 10. When FPE is used as IV, point estimates of the returns to education are low and insignificant. The Wu-Hausman test suggests, however, that the estimates cannot be distinguished from the more efficient OLS estimates which are still low, but significant.

When age of paternal orphanhood is used as IV, point estimates are larger that when FPE is used and they are significant. Estimates are also statistically different from the OLS estimates. The worker effect is estimated at 7.0%. When inputs are not controlled for, the coefficient is 9.3%. This indicates that education can have a significant and fairly large effect on agricultural production.

[7] It is not possible to make a direct comparison to cited studies that reported the returns to four years of education (see Appleton and Balihuta (1996) and Weir (1999)). However, as a proximation the 1 year marginal return estimated here can be multplied by 4 years. This leads to a worker effect of approximately 4.08% and an allocative effect of approximately 12.7% to four years of schooling. The calculation is: $100 \times (e^{educ*4} - 1)$

Table 8: 2SLS Estimates on ln(Agricultural Yields) using FPE as IV

	Worker + Allocative		Worker	
	1st Stage	2nd Stage	1st Stage	2nd Stage
Education (yrs)		0.014		-0.001
		(0.016)		(0.016)
FPE	2.120***		1.973***	
	(0.141)		(0.135)	
Female	-1.211***	-0.139***	-1.472***	-0.176***
	(0.131)	(0.044)	(0.136)	(0.044)
Age	0.180***	0.024***	0.140***	0.023***
	(0.034)	(0.008)	(0.031)	(0.007)
Age^2	-0.003***	-0.000***	-0.002***	-0.000***
	(0.000)	(0.000)	(0.000)	(0.000)
Formally Employed	2.159***	0.022	1.421***	-0.049
	(0.170)	(0.055)	(0.137)	(0.042)
Season	0.070	0.004	0.121	0.087***
	(0.114)	(0.031)	(0.105)	(0.028)
Elevation	-0.000	0.000**	-0.001	0.000
	(0.000)	(0.000)	(0.000)	(0.000)
Used Pesticides/Herbicides			0.769***	0.530***
			(0.231)	(0.098)
Ised Fertilizer - Organic			0.135	0.118***
			(0.132)	(0.036)
Fertlizer Inorganic (ln(Kg per Ha))			0.043***	0.056***
			(0.007)	(0.003)
HH Labour - Males (ln(hrs per Ha))			-0.019*	0.012***
			(0.011)	(0.003)
HH Labour - Females (ln(hrs per Ha))			0.005	0.020***
			(0.014)	(0.004)
HH Labour - Children (ln(hrs per Ha))			-0.007	0.002
			(0.009)	(0.002)
Hired Labour (ln(Days per Ha))			0.088***	0.025***
			(0.010)	(0.003)
Free Labour (ln(Days per Ha))			0.001	0.002
			(0.025)	(0.005)
Land (ln(Ha))			-0.123	-0.658***
			(0.090)	(0.071)
$Land^2$ (ln(Ha))			0.006	-0.022
			(0.026)	(0.021)
Agri implements (access index)			-0.038	0.082***
			(0.029)	(0.008)
HH Durable Goods index)			0.560***	0.041***
			(0.026)	(0.012)
District	Yes	Yes	Yes	Yes
Agroecological Zones	Yes	Yes	Yes	Yes
Observations	14567	14567	14567	14567
R^2	0.270	0.088	0.351	0.306
F-stat (first-stage)	222.092		211.449	
Hausman test (p-val)		0.239		0.392

Source: Own Calculations using Malawi's Third Integrated Household Survey, 2010/2011.
FPE uses Free Primary education as IV. * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.

Table 9: 2SLS Estimates on ln(Agricultural Yields) using Age of Paternal Orphanhood as IV

	Worker + Allocative		Worker	
	1st Stage	2nd Stage	1st Stage	2nd Stage
Education (yrs)		0.093**		0.070*
		(0.046)		(0.042)
Age Father Died	0.043***		0.041***	
	(0.007)		(0.006)	
Female	-1.097***	-0.051	-1.377***	-0.077
	(0.135)	(0.063)	(0.140)	(0.069)
Age	-0.083***	0.030***	-0.104***	0.029***
	(0.029)	(0.009)	(0.026)	(0.008)
Age^2	0.000	-0.000***	0.000	-0.000***
	(0.000)	(0.000)	(0.000)	(0.000)
Formally Employed	2.168***	-0.150	1.413***	-0.150**
	(0.174)	(0.107)	(0.139)	(0.071)
Season	0.067	-0.003	0.122	0.077***
	(0.118)	(0.032)	(0.107)	(0.029)
Elevation	-0.000	0.000**	-0.001	0.000
	(0.000)	(0.000)	(0.000)	(0.000)
Pesticides/Herbicides			0.797***	0.475***
			(0.239)	(0.104)
Fertilizer - Organic			0.147	0.106***
			(0.131)	(0.036)
Fertlizer Inorganic (ln(Kg per Ha))			0.044***	0.053***
			(0.007)	(0.003)
HH Labour - Males (ln(hrs per Ha))			-0.021**	0.013***
			(0.011)	(0.003)
HH Labour - Females (ln(hrs per Ha))			0.005	0.020***
			(0.015)	(0.004)
HH Labour - Children (ln(hrs per Ha))			-0.009	0.002
			(0.009)	(0.002)
Hired Labour (ln(Days per Ha))			0.087***	0.019***
			(0.010)	(0.005)
Free Labour (ln(Days per Ha))			0.010	0.001
			(0.025)	(0.005)
Land (ln(Ha))			-0.125	-0.649***
			(0.091)	(0.067)
$Land^2$ (ln(Ha))			0.006	-0.023
			(0.025)	(0.020)
Agri implements (access index)			-0.039	0.085***
			(0.030)	(0.008)
HH Durable Goods index)			0.572***	0.000
			(0.025)	(0.024)
District	Yes	Yes	Yes	Yes
Agroecological Zones	Yes	Yes	Yes	Yes
Observations	14567	14567	14567	14567
R^2	0.248	0.052	0.333	0.277
F-stat (first stage)	41.050		42.865	
Hausman test (p-val)		0.049		0.041

Source: Own Calculations using Malawi's Third Integrated Household Survey, 2010/2011.
Significance levels: * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.

The results show that returns to education are substantially lower in agriculture than in the formal sector. One possible reason for the low and inefficient coefficients is attenuation bias due to measurement error. There is no way of assessing the extent of possible measurement error however. In an attempt to gain more efficient estimators the IV models were also estimated using bootstrapped (with 500 repetitions) standard errors. Secondly, a sub-sample analysis was done by limiting the sample to farmers younger than 40. This was done to capture the educational shock of FPE better, by limiting confounding effects of earlier educational shocks. The results for these robustness checks are shown in Table 10. None of the estimates gained efficiency. Furthermore, the worker effect when using age of paternal orphanhood as IV becomes insignificant with bootstrapping. The sub-sample estimates did not differ significantly from the full-sample either.

Table 10: Robustness Checks

	IV	Check	Education (yrs)	Standard Error	Observations	F-Stat (first stage)
Worker + Allocative	FPE	Bootstrap	0.014	0.016	14567	310.541
		Age $\leq$ 40	0.012	0.016	8662	259.621
		Bootstrap + Age $\leq$ 40	0.012	0.016	8662	388.996
	AFD	Bootstrap	0.093**	0.046	14567	57.035
		Age $\leq$ 40	0.087	0.067	8662	17.844
		Bootstrap + Age $\leq$ 40	0.087	0.078	8662	24.134
Worker	FPE	Bootstrap	-0.001	0.016	14567	302.178
		Age $\leq$ 40	-0.005	0.015	8662	246.538
		Bootstrap + Age $\leq$ 40	-0.005	0.015	8662	367.429
	AFD	Bootstrap	0.07	0.044	14567	60.891
		Age $\leq$ 40	0.078	0.06	8662	18.05
		Bootstrap + Age $\leq$ 40	0.078	0.073	8662	25.24

Source: Own Calculations using Malawi's Third Integrated Household Survey, 2010/2011.
FPE uses Free Primary education as IV. AFD uses age of paternal orphanhood as IV. Significance levels: * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.

6 Discussion

In general, returns to education in agriculture are low but it was shown (when age of paternal orphanhood was used as IV) that education can have a significant effect on agricultural production. The results, however, also provide some further insights. To start, reasons for the lower returns in agriculture and higher returns in the formal sector are discussed. This is followed by a discussion on what the insignificant returns for the individuals entering school due to FPE imply.

6.1 Sectoral Differences in Returns to Education

If statistical significance is disregarded and focus is solely placed on point estimates, returns to education for both groups (represented by the two IVs) are lower in agriculture than in the formal sector. This supports the theoretical predictions by Welch (1970), Schultz (1975) and Ram (1980) that education has more value in modernizing environments. As noted earlier, the use of modern agricultural technologies, apart from inorganic fertilizer (much of it subsidized), was negligible.

The difference in returns between the two sectors can also be explained by two other factors. The first is that education acts in part as a screening mechanism in the formal sector. This is supported by the fact that returns in agricultural production, a more pure measure of productivity than wages, is low. Secondly, it is plausible that the education curriculum equips learners with skills more useful in the formal sector than in agriculture. Both these possibilities deserve further study.

6.2 The Quantity-quality Trade-off in Education

In both the formal sector and agricultural production, point estimates were lower when FPE was used as IV than when age of paternal orphanhood was used. Point estimates are also insignificant when FPE is used as IV. Thus, the findings suggest another explanation for why economic growth has not accompanied large improvements in access to education (see Pritchett (2001)). While quality has been stressed as one explanation, this study's results suggests two other possibilities.

Firstly, returns to education in agricultural production, where most of the employed in developing countries work, is low. Thus, increased access would not lead to high economic growth if students end up working in smallholder agriculture. Secondly, if the LATE explanation that the subgroup identified by FPE had low expected returns is to be believed the effect of increased enrolment on economic growth would also be diminished. This narrative is supported by evidence from Lucas and Mbiti (2012) and Valente (2015) who studied the effects of FPE on test scores.

Lucas and Mbiti (2012) studied the effect of FPE on test scores in Kenya of children who were already in school for three to seven years by the time it was introduced. FPE put large constraints on the Kenyan schooling system because of large increases in enrolments without a similar expansion in schools and teachers. Average test scores for the final primary schooling exam in Kenya did decline after the introduction of FPE, but the authors found that FPE only slightly decreased the test scores of learners that would have written the test in any case. The decline in average scores was driven by those who entered the schooling system after FPE was introduced. Valente (2015) analysed the effects on test scores of new entrants in the schooling system after introduction in Tanzania and found similar results. They did however find declines in test scores for students (already in school) in urban schools with high baseline test scores where there were large increases in enrolment.

Indeed, Taylor and Spaull (2013) suggested that looking at enrolment rates and average test scores in isolation are not good indicators of school quality. As a better measure of school quality, they suggested looking at the proportion of learners within a specific age group that reached certain levels of numeracy and literacy. With this measure, they found evidence that the generally accepted trade-off between quality and access in Africa is not as evident as has been believed.

7 Conclusion

Malawi is a country with high levels of poverty where a large proportion of the employed work in subsistence agriculture. Productivity levels in the sector are low and increasing it would aid in decreasing poverty in the country. This paper has studied the effects of one possible channel to achieve this - education. In the literature it was found that the empirical evidence generally only finds small positive effects for education in agricultural production. Some evidence shows that education makes individuals more likely to use technologies and also that education has larger effects in technologically advanced settings. Current evidence does not sufficiently deal with endogeneity of education in the production function.

This paper fills this gap by causally estimating the effect of education on agricultural production in Malawi. Causality is established by using an instrumental variable approach. The introduction of free primary education in the early 1990's is used as one instrument and the age of paternal orphanhood is used as a second. The instruments are shown to estimate LATE effects for two distinct groups. The FPE IV estimates returns to education for individuals who only entered school because it became free. Similarly, age of paternal orphanhood, estimates the returns for individuals who had to exit school due to paternal orphanhood.

When FPE is used as IV, point estimates are low and insignificant but similar to the significant OLS estimates. When age of paternal orphanhood is used as IV, point estimates are higher and statistically significant. This suggests that education can have an effect on agricultural production but this is not a given. Estimates suggest higher returns to education in the formal sector than in agricultural production, however. This, combined with the fact that the use of modern technologies in Malawi is negligible, supports suggestions that education is indeed more valuable in technologically advanced settings.

Finally, the low returns to education for individuals affected by FPE, suggests that large expansions in education did not have the desired effect on a subgroup of individuals at whom the expansions were aimed. Access to education was not sufficient to increase their agricultural productivity and, thus, lift them out of poverty. Access to better technologies is also needed and will compliment education as a poverty alleviation strategy. Furthermore, expansions of the formal sector also hold promise in giving educated individuals opportunities to move out of poverty.

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