Does Education Enhance Productivity in Smallholder Agriculture? Causal Evidence from Malawi.

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Abstract

Malawi is a low-income country where the majority of the population live and work in subsistence agriculture. In this setting, it is important to understand the effect of education – which is generally considered as a pathway out of poverty – on people's livelihoods. The effect of education on subsistence agricultural production has been estimated in many different settings but no studies have dealt with the endogenous nature of education in the production process. This paper contributes to the literature by estimating the causal effect of education on subsistence agricultural productivity in Malawi. To estimate the causal effect of education in agricultural production, a two-stage least squares approach is used, using the introduction of free primary education and the age of paternal orphanhood as two instrumental variables (IV) for education. The causal effect of education on the earnings of the employed is also estimated to gain a deeper understanding of the role that education plays in rural Malawi. This paper finds that there are positive returns to education in agricultural productivity, specifically in maize production and, the total value of all produce. Returns to education are higher in the earnings sector though. An interpretation of the results as a local average treatment effect suggests free primary education attracted students with lower returns to education while paternal orphanhood caused students with higher returns to exit school.

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] and 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.

Evidence supports this claim. 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 about a four times higher 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%, a growth rate of 2.17% 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).

Given these findings it is concerning that productivity growth in agriculture, in Sub-Saharan Africa (SSA), is low. Fuglie (2008) found that growth in total factor productivity (TFP) in agriculture was the lowest in SSA. SSA's average annual growth rate in TFP for the period 2000 - 2006 was 0.61%. For North and East Africa it was 1.56% while for Brazil and China it was 3.66% and 3.22% respectively. In Malawi around that same period, the growth rate of GDP per capita in smallholder agriculture was negative. For the period 2000-2005 it was -1.78% (Chirwa *et al.*, 2008).

One hypothesized channel through which agricultural production can be increased is education. Numerous have hypothesized about the possible effects of education (see Welch (1970); Ram (1980); Schultz (1975)) but Asadullah and Rahman (2009) notes that empirically there is only weak evidence that education really has positive effects . A concerning factor about the literature is a lack of causal interpretation. Most studies have used Ordinary Least Squares (OLS) to capture the average effects of education and/or used Stochastic Production Frontier (SPF) methods which measure the role of education, either in the estimation of the frontier or as an explanatory variable of inefficiency. None of the methods allow for a causal interpretation though, as they do not account for the endogeneity of education.

This study fills this gap by estimating the causal effect of education on agricultural productivity. To estimate the causal effect of education an instrumental variable (IV) approach is used. Two instruments are used for education. The first is an exogenous change in the cost of schooling with the introduction of free primary education (FPE) in Malawi. It is expected and observed that free schooling increased the years of educational attainment of learners because the costs of education decreased. The second instrument is the age of paternal orphanhood. There are numerous reasons as to why this would decrease educational attainment. Ainsworth *et al.* (2005) note that the death of parents (due to AIDS) could decrease primary school attainment of children by increasing the opportunity cost of children's time, reducing household income and thus the ability to pay school fees, and also through guardians caring

[1] Estimates are based on own calculations from Malawi's Third Integrated Household Survey which was conducted in 2010/2011. Approximately 55% of employed individuals were working in Household Agriculture while another 17% were working as ganyu labourers, which is casual labour mostly associated with household agriculture.

less about orphans' education than their own parents would have. Empirical evidence also supports these claims.

Data from Malawi's Third Integrated Household Survey, conducted in 2010/11, is used to estimate the causal effect of education. Production functions for the cash yield of crops are estimated for Malawi's rainy season. Welch (1970) showed that using a more aggregated measure of production provides opportunities to capture and distinguish between different effects of education - the worker and allocative effect. The worker effect measures the effect of education on productivity when keeping other inputs constant while the allocative effect measures the effect that education can have on farmers' ability to allocate resources more efficiently. 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 rural areas. The causal effects of education on earnings has also never been estimated for Malawi.

Using the two different instrumental variables produces distinct results. There is no effect for education on agricultural productivity if access to FPE is used as an IV while using age of paternal orphanhood as IV suggests that an extra year of education increases agricultural productivity by aproximately 9.5% on average. Estimates of the returns to education on formal sector earnings produce similar findings. Interpreting the IV's as weighted local average treatment effects, gives a clearer picture of the story. Using the age of paternal orphanhood as IV estimates the return to education for individuals who would have stayed in school had it not been for the shock. Intuitievly, these should be individuals who valued education. On the other hand, using FPE as the IV picks up the effect of education on individuals who would not have gone to school or dropped out earlier if primary schooling was not free. Intuitively these appear to be individuals who did not really see much value in education. The results suggests that giving access is to education is not enough to induce the hoped returns that education should provide.

Section 2 provides a background on agriculture and education in Malawi. Section 3 provides a literature review on the relationship between education and agriculture from both a theoretical and empirical perspective. 4 discusses the data used. The methodology is discussed in section 5. Section 6 provides the empirical results. This is followed by a discussion of the results in section 7 and section 8 concludes.

2 Agriculture and education in Malawi

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, 2014). At the national poverty line 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. The second largest sector - wholesale and retail trade - contributed between 15 and 20% of GDP over the same period (Reserve Bank of Malawi, 2014). 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 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 it is very lucrative (Orr, 2000).

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. 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)[2].

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 are 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)[3].

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. The author 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, which then creates the need to do more ganyu work. The problem is exacerbated by low ganyu wage rates.

Table 1 shows the distribution of employment over different sectors in Malawi for the working age population. Some individuals working in other sectors may also own farms. They are not included under household agriculture because their main employment sector was not household agriculture. 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 subsistence agriculture.

Educational attainment in Malawi is also 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 2 shows which learners received FPE between 1991/92 and 1994/95.

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

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

Table 1: Employment Distribution by sector

	%	Cum. %
Private	11.64	11.64
Public	3.92	15.55
Church	1.09	16.64
Self Employed	12.04	28.69
Ganyu	16.83	45.51
HH Agric	54.49	100.00

Source: Own calculations using IHS3 data. Sample is limited to the working age population which is age>=16 & age<=64. For more information on the data used please refer to section 5.

Table 2: Cohorts that received FPE

	Standard															
	Std. 1		Std. 2		Std. 3		Std. 4		Std. 5		Std. 6		Std. 7		Std. 8	
School Year	*M*	*F*	*M*	*F*	*M*	*F*	*M*	*F*	*M*	*F*	*M*	*F*	*M*	*F*	*M*	*F*
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

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 got FPE.

There is no doubt that the programmes helped increase enrolment. The increases in enrolment rates, 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).

Table 3 shows the distribution of educational attainment over the formal, informal, and self-employed sectors distiguishing also along whether individuals received at least some FPE or not. The formal sector consists of those employed in the private, public, and Church/NGO sectors while the informal sector consists of household agriculture and ganyu workers. The self-employed can be either in the formal or informal sectors (though it is mostly informal) and as such is defined on its own. Informal sector workers have by far lowest levels of education. Of those who went to school before FPE, 81.56% either had no or incomplete primary education while 93.7% had primary education or less. Of those who received at least some FPE, 65.46% had not completed primary school while 84.77% had at most completed primary school. In comparison, in the formal sector, the proportion of workers who had primary schooling or less was 53.3% if they received no FPE, and 45.35% if they received at least some FPE.

With agriculture being the dominant sector in the country where there also high poverty rates, 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.

Table 3: Educational Attainment by Sector of Employment (Pre and Post Free Primary Education)

	Formal Sector		Self Employed		Informal Sector	
	Pre %	Post %	Pre %	Post %	Pre %	Post %
Zero or Incomplete Primary	37.23	29.66	65.03	38.10	81.56	65.46
Primary	16.07	15.69	18.58	22.88	12.14	19.31
Junior Secondary	11.22	15.33	8.06	22.13	3.80	8.99
Senior Secondary	24.38	29.42	6.49	15.34	2.43	6.21
Tertiary	11.10	9.90	1.84	1.55	0.06	0.04

Source: Own calculations using IHS3 data. For more information on the data used please refer to section 5.

3 Education and agriculture

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

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

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

In many cases producers produce more than one good 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 sales 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 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 more 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 where there are higher returns (see Huffman (1980) and Fafchamps and Quisumbing (1999)). In this case, for aggregate agricultural production, education can be counter productive in that the better educated move away from the industry.

3.1 Evidence of the returns to education in agriculture

Researchers have either used Ordinary Least Squares (OLS) or Stochastic Production Frontier methods to measure the effects of education in agricultural production. Welch (1970) also showed that what effect of education you want to measure depends on how you control for inputs and what measure of production you are using. 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. They also found that the effects of education were much higher when farmers used more modern technologies. In modern environments they found that the average effect for four years of education was 9.5% while in traditional circumstances they found the average effect to be 1.3%.

The Lockheed *et al.* (1980) results should be read with caution, though. In a comment of 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 out of 22 studies in Asia had positive significant effects while for Latin America, only 3 out of 13 had positive significant effects. Only two studies of Africa, both on Kenya, were reported on. One found an insignificant effect while the other found a negative effect. In an 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.

Phillips (1994) conducted a meta-analysis of the existing evidence using an alternative method from 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.

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 of 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 primary schooling for 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 traditional agricultural settings, though effects are small. The effects do seem to be heterogeneous though, and increase with use of better technologies. Furthermore, education leads to earlier adoption of new technologies.

A lack of causal estimation of the effect of education is a striking omission from current literature though. Education is endogenous in these studies firstly because the role of individual ability is not controlled for. Higher ability can lead to both higher productivity and higher educational attainment and not accounting for it will bias the estimated effect of education. Secondly, there is also a problem of the direction of causality. 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, was associated to increases school enrollment.

3.2 Evidence on the Returns to Education in Malawi

The effect of education on agriculture in Malawi has not been studied a lot. 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. Though, the author 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 education of the household head as the education variable[4]. Returns were positive and significant and were estimated to be associated with a 3.91% increase in production on average for an extra year of education. Households where the head had 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 more than 77% more. For tobacco earnings, a year of education was associated with a 5.63% increase in earnings. Returns to schooling categories when compared to no education 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 regression with per adult equivalent expenditure divided by the poverty line (using the $1.25 per day poverty line) as dependent variable to estimate the determinants of poverty. They included both a

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

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 education in the earnings 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 returns 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 the average return to an extra year of education to be 6.61% using 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 90% confidence 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. Using robust standard errors 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. When compared with incomplete primary schooling or less, they found that those with completed primary schooling earned on average 5.08% more while those with junior and senior secondary schooling earned 9.37% and 15.38% more respectively. Similarly those with a techinical tertiary qualification earned 22.29% more while individuals with a university degree earned 65.99% more.

4 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 did the agricultural questionnaire (NSO, 2012b).

The agricultural data was collected at plot level. This implies that one household could be working many plots, and that members within a household could be in control of many plots. 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, the probability weight of each individual was divided by the number op plots he/she manages. The variables created and used in the subsequent analysis follows on Kilic *et al.* (2015) who studied gender productivity differentials in smallholder agriculture in Malawi.

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 harvested of other commodities, such as ground nuts, could also be reported as shelled or unshelled the 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 traditional authority, followed by district, and then region. Figure A4 shows the distribution of the log of monetary yields - defined as the total value of all produce divided by land size in hectars. The distribution is fairly smooth and approaches the shape of a normal distribution.

Indeces to control for wealth are also created. Both indexes are created from data from the household questionnaire. The first is a farm implements index and because it is created at the household level, it implies that it resembles access to implements. The second is a wealth index that is constructed from whether households own a range of durable goods. Both indeces are created using principal components analysis.

Table A1 gives a description of the data for other agricultural variables used. The analysis is limited to the working age population while the data on individuals is for the main decision makers of the plots. There are 16705 plots in the data however, information on harvests is only available for 14 981 plots. The average years of education of plot managers is 5.24 years which is incomplete primary education. 27% of plots are managed by females while the average age of plot managers is 38.19. Aproximately 14% of plot managers are also employed in the formal sector. Futhermore, the average household size for plot managers was 4.91 and the average child dependency ratio in the households was 1.13.

The average size of plots was 0.5 hectars whil the average yield was 65 095 Kwachas. There was fairly low use of pesticides and herbicides (2% of plots) and also of organic fertilizer (12% of plots). In terms of labour, female household members, on average, worked more on plots than male members while hired and free labour was not used much in general. Plots were on average 830 meters away from households while the median distance was 500 meters.

For the formal sector in Malawi earnings are reported on the main jobs individuals had in the last 12 months. Only the earnings of those who were still employed in formal sector at the time of their interview were considered. Ganyu wages were reported as daily rates but are converted to monthly equivalents assuming an average of 21.67 working days per month[5]. Table A2 provides a description of the data for

[5] 21.67 is an approximate of the average number of working days per month if it is assumed that there are 52 weeks in a year and 5 working days in a week ($\frac{52*5}{12}$).

formal sector employees that is used for the estimates of earinings regressions. Formal sector employees generally live in houses with less people and lower child dependency ratios while they also have higher levels of education with 8.45 years of education on average. Figure A5 show the distribution of formal sector sector wages.

5 Methodology

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

$$\begin{aligned} S_i &= X_i\beta + Z_i\gamma + \mu_i \\ Y_i &= X_i\beta + S_i\alpha + \varepsilon_i \end{aligned}$$

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 $N\left(0, \sigma^2\right)$.

Cobb-Douglas type production functions are used to model agricultural yields. The log of cash yield is modeled on the log of numerous inputs into the production process. Inputs into the production process include land, household labour, capital, the use of fertilizer, pesticides and herbicides, and, also the use of outside labour. The indeces fot access to farm impliments, and, also wealth are also controlled for and are also assumed to be inputs into the production process.

To account for rainfall and other climatic factors, regions, elevation, agro-ecological zones, and season of harvest are controlled for. Other controls inlude the distance from a household to plots, the distance from households to ADMARC centres, whether households received agriculture extension services, and household characterisitics such as household size and child dependency ratios. Finally individual characteristics which could affect production, such as gender, age, whether plot managers are married, and, of course, education are included.

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.

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 are made. When the effect of education on the total value of production is estimated, 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-hyputhesis 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 dependant 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.

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 exogenous shock is expected to have increased the demand for schooling which would have led to an increase in enrolment in primary schooling. As such a variable capturing whether individuals benefited from this policy change or not should be correlated with the amount of schooling received but not 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 everyone who was of school going age (6 years) when it was first implemented and after that gets the treatment. Thus, individuals who were 6 years old in 1991 or thereafter gets a value of 1 which captures full treatment. Secondly, given that many students start school earlier or later, a 1 was also given to all students who started school in 1991. Finally, many students were already in primary school when FPE was introduced. For them, assuming no repetition, it was calculated aproximately where in primary school they were when FPE was introduced using their educational attainment and the year that they stopped school in. For example boys who were in grade 5 in 1991/92 would have been in grade 8 in 1994/95. Thus, they would have gotten 1 out of 8 years of primary education free. They are then given 1/8 in the treatment variable. Individuals who were already in secondary school when changes were introduced were given a 0. Thus the treatment variable could take any value from 0 to 1 in jumps of 1/8. Table A3 give the number of observations for each level of access to FPE for the agricultural production and earnings estimation samples.

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 correlated with productivity or earnings in the long term.

There are many studies that 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 or both of their parents while in 2000 that rate was 11.7%. For the same age group, the rates of paternal orphanhood were 4.6% in 1992 and 6.5% in 2000, while for maternal orphanhood the rates were 3% in 1992 and 2.9%. Further, regressions for school enrolment in Malawi indicated that orphans were significantly less likely to be enrolled in school as 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. For both years the negative effects of maternal orphanhood were greater than paternal orphanhood. Using a 5 year Kenyan panel data set Evans and Miguel (2007) 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.

It is possible to argue that paternal orphanhood could be correlated with production if for example it is correlated with socio-economic status which could be correlated with production. Yet one can control for wealth in production functions. 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 prove their own worth 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 died yet. This assisted in dealing with missing values on parental death as well as those whose parents died at a later age because death at any later age should not influence educational attainment. There are possibly a few candidates that would still be in tertiary education at or after the age of 25 but they are few and are not expected to influence the results much. Rigobon and Stoker (2005) showed that truncated instrumental variables do not bias estimates in general. Speecifically, if an uncensored version of the variable is observed and it is a valid instrument then censoring it still produces a valid instrument. Table A4 gives the number of observations for each age of paternal death for the argiculture and earnings estimation samples.

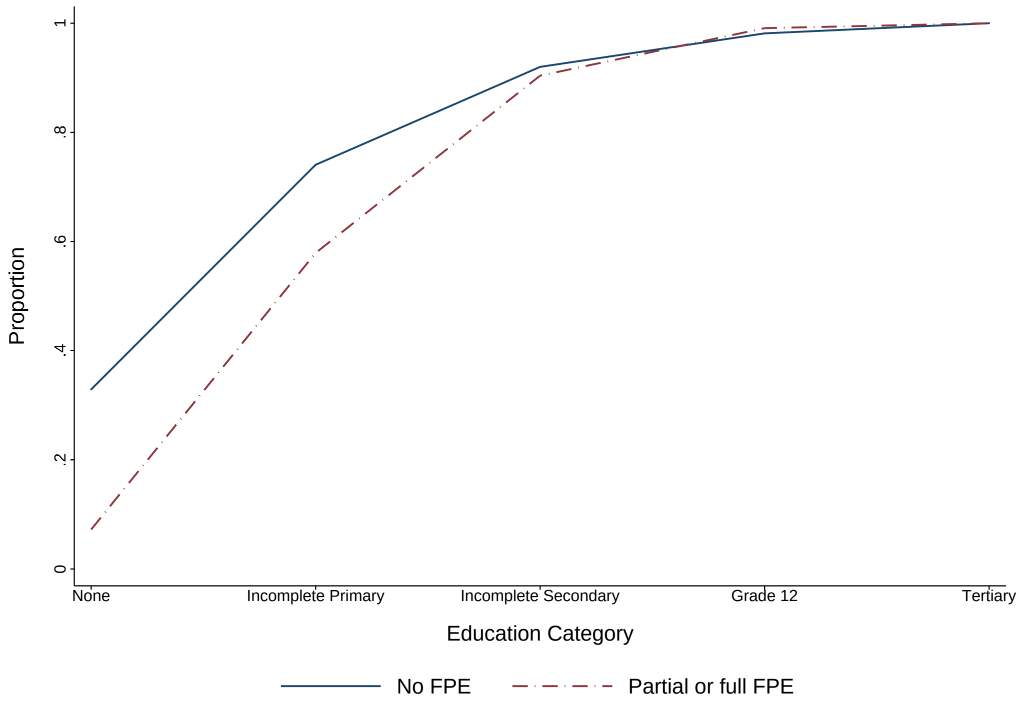
Angrist and Imbens (1995) show that where IV's have variable treatment intensity 2SLS estimates can be interpreted as an Average Causal Response (ACR) which is a weighted average of the effect of the endogenous variable on the outcome for those whose behaviour was altered because of the exogenous treatment effect, if two assumptions are satisfied. 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.

For the above estimations the ACR measures the effect of education on those individuals whose behaviour was altered because of FPE and paternal orphanhood. With regards to FPE this implies that the estimate captures the effect of education on those who would never have attended school if schooling was not free, and also of those who were already in the schooling system, and would have dropped out earlier in primary school had education not become free while they were in school. 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.

Angrist and Imbens (1995) note that it is possible to get an idea about whether the monotonicity assumption holds by looking at whether cumulative distributions 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.

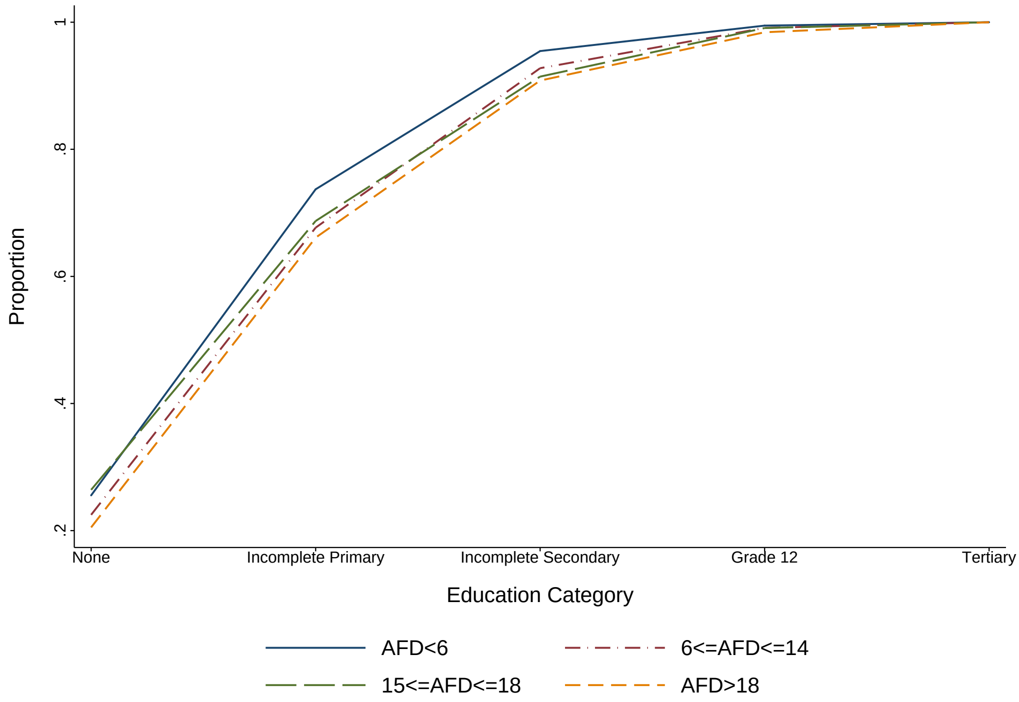
Treatment groups are specified because sample sizes are very small if the CDF of education is calculated at each age for paternal orphanhood and at each treatment level of FPE. With regards to FPE a person can either fall into the group that received no FPE or the group that received partial or full FPE. 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 1 shows the CDF of education for those who received no FPE and those who received partial or full FPE. Figure 2 shows the CDF of education by different age groups of paternal orphanhood. 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 should be on primary schooling, the figure suggests that the mononicity 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 has negative effects on education.

Figure 1: Cumulative Distribution Functions of Education for Individuals who received no FPE and those that received at least partial FPE.



Source: Own calculations using IHS3 data. FPE refers to free primary education.

Figure 2: Cumulative Distribution Functions for Education for Different Age Groups of Paternal Orphanhood

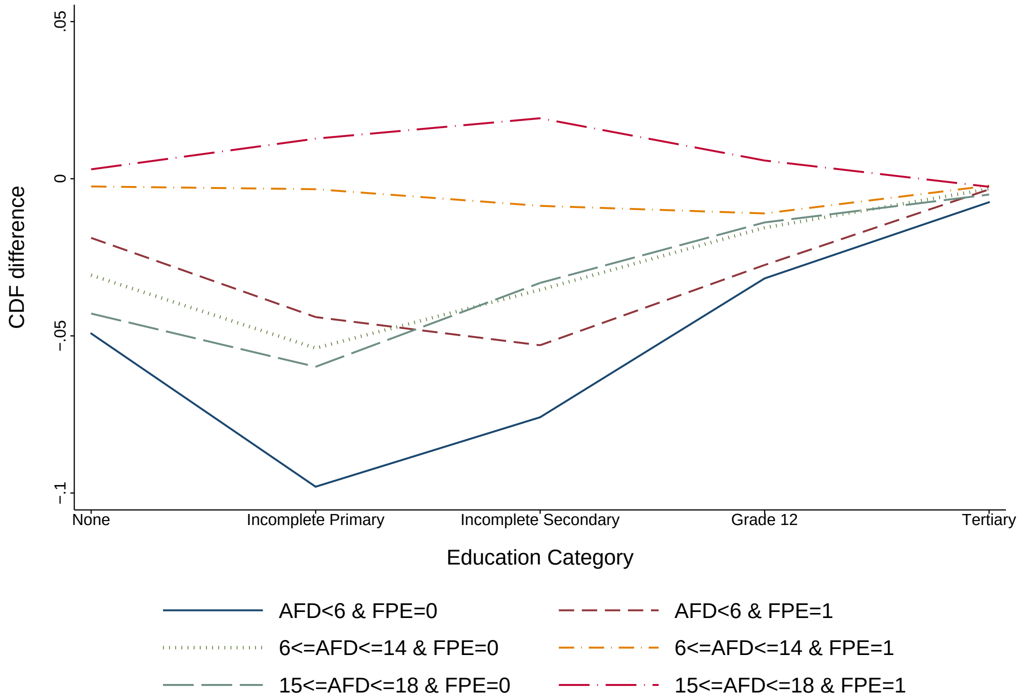


Source: Own calculations using IHS3 data. AFD refers to the age an individual's father died at.

To illustrate the effects of the instruments in more detail , differences between the CDFs of those that received no treatment and those 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. As an example of who is compared to whom, 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 died when they were younger the 6 years old and who did receive FPE, is subtratced from the CDF of those whose father was still alive by the time that they were 19 and who received FPE. Figure 3 shows the CDF differences.

From figure 3 is generally clear that paternal orphanhood during or before school negatively affects schooling outhcomes. 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 because after the introduction of FPE, income was less of a concern.

Figure 3: IV distributional Shocks



Source: Own calculations using IHS3 data. FPE refers to free primary education where FPE=0 means no FPE while FPE=1 means partial or full FPE. AFD refers to the age an individual's father died at.

Intuitively, it is expected that students who only entered school because of FPE would have had low inherent returns to education. 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 inherent returns. They would have been individuals who did see value of investing in education.

Other research has generally found that IV estimates of the returns to education tend to be higher than OLS estimates. Trostel *et al.* (2002) estimated the returns to education in earnings for a number of countries using consistent data. They found that in general, IV estimates based on family characteristics were approximately 20% higher than OLS estimates[6]. In a review of the IV estimates using institutional features of the schooling system, Card (1999) found that IV estimates are often 30% higher than OLS estimates.

The model is estimated using the IVRegress command in STATA and selecting the 2SLS estimator. The SVY command in STATA is used to account for a two-stage survey design. The data was stratified at the district level and from there enumeration areas were selected. One problem with using the svy command is that the post estimation statistics cannot be estimated if IVRegress was used. Thus, for the post estimation tests, models were estimated again using only standard probability weighting, with clustering at the household level. For both the use of SVY and standard probability weighting, the weights were adjusted to reflect the number of plots managed by individuals.

[6] The instrumental variables used were mother's (8 countries), father's (9 countries), and spouse's (10 countries) education.

6 Empirical Results

Agriculture production functions are presented first followed by earnings functions[7]. As a start, OLS regressions are shown in table 4. 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 allocative + worker effect of education. In this model personal, household, and, plot characterisitics 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 aproximation of the allocative effect of education.

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 suggests that there is an allocative effect of education and this effect is significant as indicated through the Wald Test. Results suggest that an extra year of education is associated with aproximately a 1.2% and 3.1% increase in yields on average when inputs are controlled for and when they or not, respectively.

In terms of the control variables, the results are generally consistent with what would be expected. All inputs have a positive and significant correlation with yields while land size has a significantly negative correlation, which is consistent with the inverse productivity hypothesis.

[7] For a more detailed version of the agricultural estimates please refer to the appendix

Table 4: OLS Estimates of the Returns to Education in Agricultural Production

	OLS1	OLS2	OLS3
Education (yrs)	0.044***	0.031***	0.012***
	(0.003)	(0.004)	(0.003)
Pesticides/Herbicides			0.482***
			(0.105)
Fertilizer - Organic			0.102***
			(0.036)
Fertlizer Inorganic (ln(Kg per Ha))			0.039***
			(0.002)
HH Labour - Males (ln(hrs per Ha))			0.039***
			(0.006)
HH Labour - Females (ln(hrs per Ha))			0.050***
			(0.008)
HH Labour - Children (ln(hrs per Ha))			0.006
			(0.006)
Hired Labour (ln(Days per Ha))			0.021***
			(0.002)
Free Labour (ln(Days per Ha))			0.006*
			(0.004)
Land (ln(Ha))			-0.570***
			(0.072)
$Land^2$ (ln(Ha))			-0.013
			(0.022)
Agri implements (access index)			0.082***
			(0.009)
HH Durable Goods index)			0.048***
			(0.008)
Personal details	No	Yes	Yes
Plot characteristics	No	Yes	Yes
Household details	No	Yes	Yes
Observations	14560	14551	14383
R^2	0.024	0.060	0.282
Allocative Effect (Wald Test):			
F-Stat			59.218***

Source: Own calculations using IHS3 data. 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.

Next, we move on to the 2SLS estimates which are shown in table 5. 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-values of the Wu-Hausman test is also shown. Under the test the efficient OLS estimator is compared to the consistent IV estimator. Under the null-hypothesis there are no systematic differences in the coefficients of the two models.

The instruments all seem to be strong with the first-stage F-statistic well above 10. The effect of education is not efficiently estimated though as the standard errors are large. When using FPE as instrument, the returns to education are basically 0. Even with large standard errors the point estimates are also 0. This suggest that education had no effect on productivity for individuals who only entered school because of FPE. On the other hand, the point estimates when using the age of paternal orphanhood as instrument are large, and the effect is significant when inputs are not controlled for. This suggests that the initial expectations are confirmed that the LATE effects of FPE and age of paternal orphanhood are distinguishing between individuals with low and high inherent returns, respectively.

Table 5: 2SLS Estimates of the Returns to Education in Agricultural Production

	Worker + Allocative			Worker		
	FPE	AFD	Both	FPE	AFD	Both
Education (yrs)	0.000	0.095**	0.034	-0.005	0.072	0.020
	(0.030)	(0.048)	(0.024)	(0.027)	(0.044)	(0.022)
Inputs	No	No	No	Yes	Yes	Yes
Observations	14551	14551	14551	14383	14383	14383
Adjusted R^2						
F-Stat (firststage)	73.039	41.891	57.835	78.797	41.751	61.585
Hausman test (p-val)	0.192	0.046	0.888	0.413	0.040	0.611

Source: Own calculations using IHS3 data. 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.

In an attempt to gain more efficiency and as robustness checks, the estimates were also bootstrapped (with 500 repetitions), and also calculated by dropping outliers - defined as plots with yields below the 1st and above the 99th percentiles of the yield distribution. The bootstrapped estimates do produce more efficient estimates and suggest a similar story to the main results. Dropping outliers makes all the results insignificant and does also not produce more efficient results. The 2SLS estimate using age of paternal orphanhood as IV produces lower point estimates when outliers are excluded. This suggests that there are a few plots with very high yields that belong to farmers in the group affected by that IV.

For the estimates of earnings of the employed, the control variables are also correlated with earnings, in the manner expected. There are decreasing marginal returns to age, while rural individuals and women earn less on average. Compared to the private sector, those who work in the public and church/NGO sectors earn significantly more.

The returns to education seem to be larger than in the agricultural sector. The OLS estimate of the return to education suggests that an extra year year of education is associated with approximately a 10% increase in earnings on average. The 2SLS estimates suggest a similar pattern to the agricultural estimates with no returns to education for those who entered school due to FPE while there are high and significant returns for individuals who had to drop out of school due to paternal death. Also, the 2SLS estimate when both instruments are included, lies between the estimates when instruments are included individually. In this case though the estimate is significant as well. One problem is that the estimate using FPE as instrument suffers from a weak instrument problem as the first-stage F-statistic is only 6.69. Weak instruments lead to large standard errors, and also inconsistent estimates of the variable of interest (Bound *et al.*, 1995). The other results are more consistent with lower standard errors. The results suggest that education does have a causal effect on earnings and that OLS estimate is a good approximation of the effect.

Table 6: Formal Sector Earnings Estimates

	OLS1	OLS2	2SLS Estimates+ FPE	2SLS Estimates+ AFD	2SLS Estimates+ Both
Education (yrs)	0.127***	0.102***	0.004	0.125***	0.088***
	(0.006)	(0.006)	(0.082)	(0.043)	(0.032)
Age		0.074***	0.093***	0.069***	0.077***
		(0.011)	(0.020)	(0.014)	(0.013)
Age^2		-0.001***	-0.001***	-0.001***	-0.001***
		(0.000)	(0.000)	(0.000)	(0.000)
Sector(ref = Private)		ref.	ref.	ref.	ref.
Public		0.305***	0.628**	0.229	0.353***
		(0.047)	(0.281)	(0.146)	(0.117)
NGO/Church		0.267***	0.498**	0.213	0.301**
		(0.095)	(0.210)	(0.141)	(0.126)
Rural		-0.332***	-0.547***	-0.281***	-0.364***
		(0.039)	(0.181)	(0.108)	(0.080)
Female		-0.064	-0.082	-0.060	-0.067*
		(0.040)	(0.051)	(0.040)	(0.040)
Married		0.038	0.113	0.020	0.049
		(0.044)	(0.085)	(0.057)	(0.053)
Household size		0.021**	0.020**	0.022**	0.021**
		(0.008)	(0.009)	(0.009)	(0.008)
Child dependency ratio		-0.075**	-0.154**	-0.056	-0.086**
		(0.032)	(0.068)	(0.048)	(0.040)
Region	No	Yes	Yes	Yes	Yes
Observations	2956	2956	2956	2956	2956
R^2	0.293	0.384	0.250	0.377	0.381
Weak ID F-stat			6.691	13.920	9.700
Wu-Hausman p-val			0.116	0.574	0.670

Source: Own calculations using IHS3 data. 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.

7 Discussion

From the results, there seem to be small benefits to acquiring more education in agriculture. By comparing the worker effect with the allocative effect, it seems that education helps make farmers more productive using the inputs they have, and that it helps farmers by improving their general decision making proses regarding the use of other inputs and also what crops to plant.

Even though the IV estimates are estimated inefficiently, there is a general pattern across all estimates suggests that there are no returns to education in subsistence agriculture for individuals who entered school due to FPE. This is discouraging. There are two reasons as why this could be the case. The first is that individuals who entered school because of FPE experienced a much more constrained schooling system (which was discudsed earleier) and this could have affected the quality of the education they received.

The second is that individuals who entered school because of FPE had lower inherent returns. This explanation is supported by evidence from Lucas and Mbiti (2012) who studied the effects of FPE in Kenya. 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. Both reasons most likely hold some merit and there remains the possibility that good quality education could have had a positive causal effect for these low return individuals.

These findings also suggest another explanation for the fact that over the past couple of decades there have been large improvements in access to education across the world without the economic growth that was expected to accompany it (see Pritchett (2001). While quality has been stressed one explanation, this study's results suggests another possibility. FPE has attracted many students who did not have high returns to education that have dampened many of the possible positive effects of education expansion. Taylor and Spaull (2013) suggested that looking at enrollment 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 tradeoff between quality and access in Africa is not as evident as has been believed.

On the other hand the estimates suggested that there were large returns for individuals who had to leave school due to paternal orphanhood. In both the formal earings sector and agricultural production the effect was significant. It suggests that education had a causal effect on the productivity of these individuals with and extra year of education leading to approximately a 10% increase in productivity.

8 Conclusion

Malawi is a country with high levels of poverty where a large proportion of the employed work in subsistence agriculture. Increasing agricultural production is key to poverty reduction. 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. There is some evidence that education makes individuals more likely to use newer technologies and also that education has larger effects in technologically advanced settings. The one problem with much of the evidence, especially in production estimates, is a lack of causal evidence.

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. These two instruments identify two distinct local average treatment effects.It is found that education can have a positive effect on agricultural production, depending on the IV used.

These two IV's distinguish between individuals who valued investment in education and those who did not. No effect was found for students who entered primary school because it became free, while education had a 10% increase in productivity for individuals who were in school but had to drop out due to paternal orphanhood. Similar effects were also observed in the formal wage sector. This suggests that access alone is not enough for individuals to receive gains from education and that other measures need to be used to make individuals want the benefits and returns that education can give.

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A Full Tables

Table A1: Agriculture Data Description - Plot Level

	Mean	Median	Min	Max	Obs
Education (yrs)	5.24	5.00	0.00	15	16620
Female	0.27	0.00	0.00	1	16705
Married	0.79	1.00	0.00	1	16705
Age	38.19	36.00	15.00	64	16705
Formally Employed	0.14	0.00	0.00	1	16705
Yield per Ha (Kwachas)	65094.57	30107.56	0.00	14030563	14981
Pesticides/Herbicides	0.02	0.00	0.00	1	16466
Fertilizer - Organic	0.12	0.00	0.00	1	16474
Fertlizer Inorganic (Kg per Ha)	158.37	93.60	0.00	21886	16705
HH Labour - Males (hrs per Ha)	443.16	271.21	0.24	30023	16705
HH Labour - Females (hrs per Ha)	523.58	335.36	0.44	34348	16705
HH Labour - Children (hrs per Ha)	84.66	1.00	0.12	27676	16705
Hired Labour (Days per Ha)	6.54	0.00	0.00	3459	16705
Free Labour (Days per Ha)	0.95	0.00	0.00	1483	16705
Plotsize (Ha)	0.50	0.33	0.00	295	16092
HH Agri implements index	0.06	-0.28	-2.18	34	16486
HH Durable Goods index	-0.49	-1.13	-1.54	20	16704
Season^{+}	0.56	1.00	0.00	1	16705
Elevation	885.79	937.00	38.00	1688	16705
Plot-HH km	0.83	0.50	0.00	10	16120
Household size	4.91	5.00	1.00	19	16705
Child dependency ratio	1.13	1.00	0.00	8	16705
Extension services (received)	0.11	0.00	0.00	1	16705
Distance to Admarc (km)	7.89	6.70	0.05	38	16705
Rural	0.93	1.00	0.00	1	16705

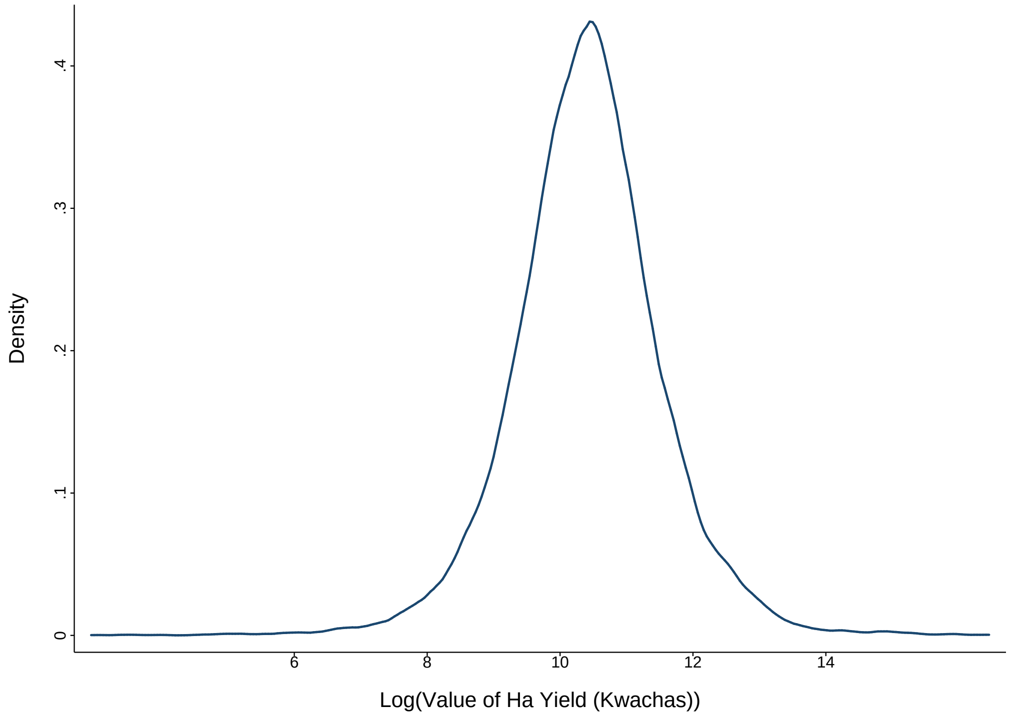
Source: Own calculations using IHS3 data. $^{+}$For season, 2008/2009=0 and 2009/2010=1.

Table A2: Data Description for Formal Sector Employees

	Mean	Median	Min	Max	Obs
Education (yrs)	8.45	9.00	0.00	15	3004
Female	0.20	0.00	0.00	1	3080
Married	0.78	1.00	0.00	1	3080
Age	35.07	33.00	15.00	64	3080
Rural	0.59	1.00	0.00	1	3080
Household size	4.82	5.00	1.00	18	3080
Child dependency ratio	0.85	0.67	0.00	5	3080

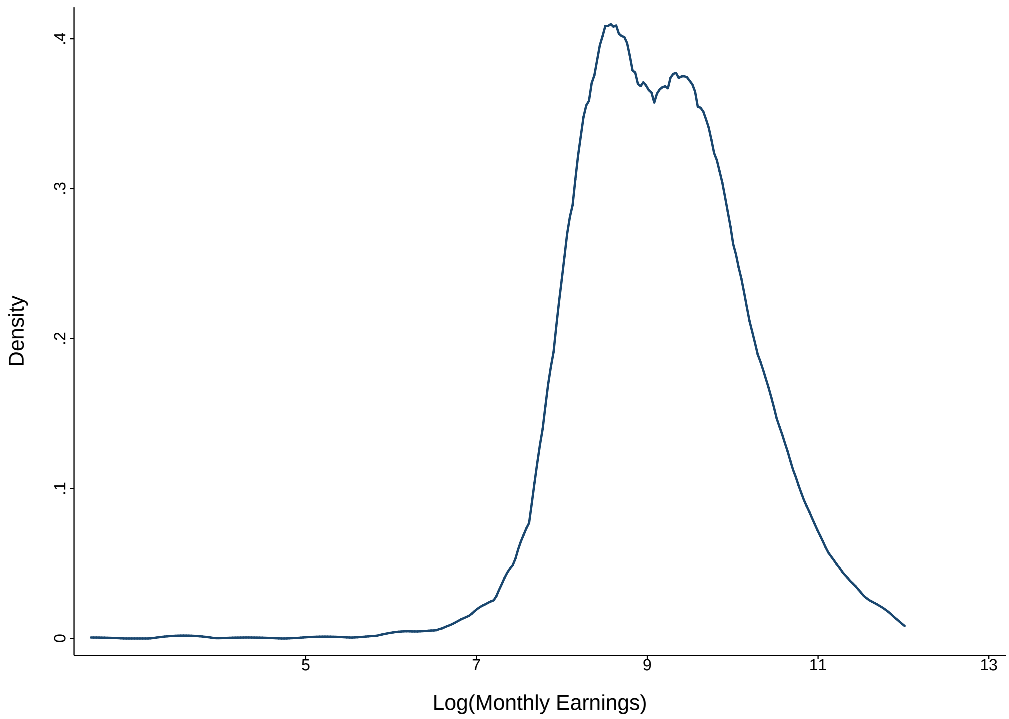
Source: Own calculations using IHS3 data.

Figure A4: Distribution of yields



Source: Own calculations using IHS3 data.

Figure A5: Distribution of Formal Sector Wages



Source: Own calculations using IHS3 data.

Table A3: Distribution of access to free primary education

	Agriculture	Wages
0	11422	2048
0.125	0	0
0.25	195	97
0.375	243	90
0.5	255	73
0.625	49	14
0.75	54	31
0.875	79	24
1	2086	579

Source: Own calculations using IHS3 data.

Table A4: Age of Paternal Orphanhood Frequency

	Agriculture	Wages
0	52	7
1	134	16
2	98	19
3	121	12
4	104	16
5	90	23
6	102	25
7	149	21
8	143	27
9	77	19
10	288	66
11	123	19
12	252	67
13	133	36
14	231	42
15	433	76
16	184	40
17	187	52
18	295	51
19	213	47
20	535	103
21	203	35
22	263	55
23	198	44
24	194	50
>=25	9581	1988

Source: Own calculations using IHS3 data.

Table A5: Full OLS Estimates

	OLS1	OLS2	OLS3
Education (yrs)	0.044***	0.031***	0.012***
	(0.003)	(0.004)	(0.003)
Female		-0.101**	-0.156***
		(0.041)	(0.040)
Age		0.028***	0.026***
		(0.008)	(0.007)
Age^2		-0.000***	-0.000***
		(0.000)	(0.000)
Formally Employed		0.008	-0.052
		(0.046)	(0.039)
Season		0.028	0.106***
		(0.037)	(0.035)
Elevation		0.000***	0.000***
		(0.000)	(0.000)
Plot-HH km		-0.002	0.011
		(0.010)	(0.009)
Household size		0.014*	-0.002
		(0.008)	(0.007)
Child dependency ratio		-0.056***	-0.009
		(0.018)	(0.016)
Extension services (received)		0.020	-0.037
		(0.061)	(0.050)
Distance to Admarc (km)		-0.002	0.001
		(0.003)	(0.003)
Rural		-0.042	0.161*
		(0.099)	(0.082)
Pesticides/Herbicides			0.482***
			(0.105)
Fertilizer - Organic			0.102***
			(0.036)
Fertlizer Inorganic (ln(Kg per Ha))			0.039***
			(0.002)
HH Labour - Males (ln(hrs per Ha))			0.039***
			(0.006)
HH Labour - Females (ln(hrs per Ha))			0.050***
			(0.008)
HH Labour - Children (ln(hrs per Ha))			0.006
			(0.006)
Hired Labour (ln(Days per Ha))			0.021***
			(0.002)
Free Labour (ln(Days per Ha))			0.006*
			(0.004)
Land (ln(Ha))			-0.570***
			(0.072)
$Land^2$ (ln(Ha))			-0.013
			(0.022)
Agri implements (access index)			0.082***
			(0.009)
HH Durable Goods index)			0.048***
			(0.008)
Region	No	Yes	Yes
Agroecological Zones	No	Yes	Yes
Observations	14560	14551	14383
R^2	0.024	0.060	0.282
Allocative Effect (Wald Test):			
F-Stat			59.218***

Source: Own calculations using IHS3 data. 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.

Table A6: Full Instrumental Variable Estimates

	Worker + Allocative			Worker		
	FPE	AFD	Both	FPE	AFD	Both
Education (yrs)	0.000	0.095**	0.034	-0.005	0.072	0.020
	(0.030)	(0.048)	(0.024)	(0.027)	(0.044)	(0.022)
Female	-0.139**	-0.023	-0.098*	-0.181***	-0.067	-0.144***
	(0.057)	(0.070)	(0.051)	(0.056)	(0.074)	(0.050)
Age	0.026***	0.032***	0.028***	0.025***	0.031***	0.027***
	(0.008)	(0.009)	(0.008)	(0.007)	(0.009)	(0.007)
Age^2	-0.000***	-0.000***	-0.000***	-0.000***	-0.000***	-0.000***
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Formally Employed	0.073	-0.129	0.002	-0.027	-0.139*	-0.064
	(0.081)	(0.109)	(0.069)	(0.056)	(0.074)	(0.052)
Season	0.033	0.019	0.028	0.109***	0.096***	0.104***
	(0.037)	(0.039)	(0.037)	(0.035)	(0.036)	(0.035)
Elevation	0.000***	0.000***	0.000***	0.000***	0.000***	0.000***
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Plot-HH km	-0.001	-0.006	-0.003	0.011	0.012	0.012
	(0.011)	(0.011)	(0.010)	(0.009)	(0.009)	(0.009)
Household size	0.017*	0.009	0.014	-0.002	-0.002	-0.002
	(0.009)	(0.009)	(0.008)	(0.007)	(0.007)	(0.007)
Child dependency ratio	-0.068***	-0.030	-0.055**	-0.013	0.005	-0.007
	(0.023)	(0.028)	(0.021)	(0.018)	(0.019)	(0.017)
Extension services (received)	0.028	0.003	0.019	-0.035	-0.046	-0.039
	(0.063)	(0.063)	(0.062)	(0.050)	(0.052)	(0.050)
Distance to Admarc (km)	-0.003	-0.000	-0.002	0.001	0.002	0.001
	(0.003)	(0.003)	(0.003)	(0.003)	(0.003)	(0.003)
Rural	-0.104	0.087	-0.036	0.150*	0.200**	0.166*
	(0.120)	(0.138)	(0.114)	(0.082)	(0.095)	(0.085)
Pesticides/Herbicides				0.496***	0.432***	0.475***
				(0.107)	(0.113)	(0.107)
Fertilizer - Organic				0.105***	0.089**	0.100***
				(0.037)	(0.037)	(0.037)
Fertlizer Inorganic (ln(Kg per Ha))				0.040***	0.037***	0.039***
				(0.002)	(0.003)	(0.002)
HH Labour - Males (ln(hrs per Ha))				0.038***	0.041***	0.039***
				(0.006)	(0.006)	(0.006)
HH Labour - Females (ln(hrs per Ha))				0.050***	0.050***	0.050***
				(0.008)	(0.008)	(0.008)
HH Labour - Children (ln(hrs per Ha))				0.006	0.006	0.006
				(0.006)	(0.006)	(0.006)
Hired Labour (ln(Days per Ha))				0.022***	0.017***	0.020***
				(0.003)	(0.004)	(0.003)
Free Labour (ln(Days per Ha))				0.006*	0.006*	0.006*
				(0.004)	(0.004)	(0.004)
Land (ln(Ha))				-0.571***	-0.567***	-0.570***
				(0.074)	(0.068)	(0.072)
$Land^2$ (ln(Ha))				-0.013	-0.014	-0.013
				(0.022)	(0.020)	(0.022)
Agri implements (access index)				0.082***	0.082***	0.082***
				(0.009)	(0.009)	(0.009)
HH Durable Goods index)				0.058***	0.013	0.043***
				(0.017)	(0.026)	(0.015)
Region	Yes	Yes	Yes	Yes	Yes	Yes
Agroecological Zones	Yes	Yes	Yes	Yes	Yes	Yes
Observations	14551	14551	14551	14383	14383	14383
Adjusted R^2						
Fstat	73.039	41.891	57.835	78.797	41.751	61.585
HW	0.192	0.046	0.888	0.413	0.040	0.611

Source: Own calculations using IHS3 data. FPE uses Free Primary education as IV. AFD uses age of paternal oprhanhood as IV. Significance levels: * p<0.1, ** p<0.05, *** p<0.01.

Table A7: Returns to Education - Bootstrapped Estimates

	Worker + Allocative			Worker		
	FPE	AFD	Both	FPE	AFD	Both
Education (yrs)	0.000	0.095*	0.034	-0.005	0.072	0.020
	(0.031)	(0.050)	(0.023)	(0.026)	(0.046)	(0.023)
Inputs	No	No	No	Yes	Yes	Yes
Observations	14551	14551	14551	14383	14383	14383
Adjusted R^2	0.049	0.019	0.058	0.278	0.249	0.280
F-Stat (firststage)	91.548	55.453	76.116	105.790	58.354	81.776
Hausman test (p-val)	0.192	0.046	0.888	0.413	0.040	0.611

Source: Own calculations using IHS3 data. FPE uses Free Primary education as IV. AFD uses age of paternal oprhanhood as IV. Significance levels: * p<0.1, ** p<0.05, *** p<0.01.

Table A8: Returns to Education - Outliers Removed

	Worker + Allocative			Worker		
	FPE	AFD	Both	FPE	AFD	Both
Education (yrs)	-0.000	0.055	0.019	-0.006	0.045	0.011
	(0.028)	(0.043)	(0.023)	(0.025)	(0.040)	(0.021)
Inputs	No	No	No	Yes	Yes	Yes
Observations	14254	14254	14254	14088	14088	14088
Adjusted R^2						
F-Stat (firststage)	73.781	39.775	57.537	79.997	40.044	61.837
Hausman test (p-val)	0.162	0.352	0.556	0.333	0.205	0.938

Source: Own calculations using IHS3 data. FPE uses Free Primary education as IV. AFD uses age of paternal oprhanhood as IV. Significance levels: * p<0.1, ** p<0.05, *** p<0.01.