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# Rural households' participation in charcoal production in Zambia: Does agricultural productivity play a role?

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ABSTRACT

The study uses a nationally representative dataset of smallholder farmers in Zambia to determine the effect of agricultural productivity on households' participation in charcoal production. An instrumental variable probit approach is applied to account for the endogeneity of agricultural productivity in household's charcoal participation decision. We find a negative and significant effect of agricultural productivity on household's likelihood of participation in charcoal production. Results also show that higher education, income, asset value, and participation in off-farm employment opportunities reduce the likelihood of participation in charcoal production. Therefore, interventions seeking to reduce charcoal production in rural Zambia could benefit from improving smallholder agricultural productivity, incomes, asset base, and off-farm employment creation. However, interventions need not lose sight of other important macro-level factors.



## Introduction

In Zambia like many other parts of sub-Saharan Africa (SSA), charcoal is one of the most important sources of energy for cooking and space heating among urban households. A comprehensive review of literature on charcoal and livelihoods in SSA by Zulu and Richardson (2013) indicates that about 80% of the urban population in the region relies on charcoal for cooking. Furthermore, a study by Tembo et al. (2015) on cooking fuel choice among urban households in Zambia finds 82% of urban households to be charcoal users. Demand for charcoal is likely to remain high in the foreseeable future, owing to the rising urban population, erratic electricity supply, high electricity tariffs, and few affordable alternatives. In addition most SSA countries are still struggling to formulate concrete policies promoting alternative energy sources.

On the supply side, almost all the charcoal is produced in rural areas but consumed in urban areas, with the majority of producers being smallholder farmers (Tembo et al., 2015; Kalinda et al., 2013; Mwitwa and Makano, 2012; Vinya et al., 2012). In fact, even if charcoal producers may not necessarily be farmers who produce enough for subsistence and/or sale, they usually have a small piece of land for food production within the home (Mulenga et al., 2014). Thus, charcoal is an important source of income for rural smallholder farmers, providing a steady flow of income for producers throughout the year (Mwitwa and Makano, 2012). However, charcoal has also been linked to a number of adverse environmental and health effects. These include localized deforestation and degradation, emission and inhalation of carbon monoxide during production. One of the longstanding debates regarding charcoal in SSA and Zambia in particular, is its effect on deforestation and forest degradation. In Zambia, charcoal has been identified as one of the main drivers of deforestation and degradation (Tembo et al., 2015; Government of the Republic of Zambia, 2014; Vinya et al., 2012). With the projected increase in charcoal demand and consequently production, there is need for analyses that would inform the design of interventions aimed at reducing charcoal production, without jeopardizing the livelihood of its producers. Given that majority of charcoal producers in Zambia are smallholder farmers, understanding the interaction between charcoal production and agricultural productivity is a useful input in designing such interventions.

A number of studies in Zambia and SSA identify low agricultural productivity and low agricultural income as being among the important household level supply side drivers of charcoal production (Arnold et al., 2006; Chidumayo, 2002; Mwitwa and Makano, 2012; Zulu and Richardson, 2013). These studies provide a foundation for understanding the linkages between agricultural productivity and participation in charcoal production. However,

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exploring this interaction is not the main focus of these studies. Furthermore, most of the existing studies in Zambia and SSA have relied on descriptive analysis, or small samples from selected regions of the country (e.g. Chidumayo, 2002; Mwitwa and Makano, 2012; Khundi et al., 2011). To the best of our knowledge, there are no empirical studies in Zambia or SSA that use a sample of national scope and control for potential endogeneity of agricultural, and much less quantify the effect of agricultural productivity on households' participation in charcoal production and/or sale.[1] An exception here could be Khundi et al. (2011) who model determinants of household participation in charcoal production and sale in Uganda by controlling for household level factors. However, their analysis does not directly address the question of whether agricultural productivity affects participation in charcoal production, but rather assesses the effect of agricultural capacity, measured in terms of agricultural tools owned by a household. Hence, very little is known in terms of the effect of agricultural productivity as a tool in helping address the rising charcoal production. Filling this knowledge gap is the main aim of this study.

Against this backdrop, the contribution of this study is twofold. First, the study is one of the first in sub-Saharan Africa to use nationally representative household level data to empirically and more directly address the question of whether agricultural productivity affects rural households' participation in charcoal production, as well as quantify this effect. Secondly, the study accounts for the potential endogeneity of agricultural productivity, thus providing more reliable estimates of the effects of agricultural productivity on households' participation in charcoal production. Most existing studies assume that agricultural productivity is exogenous to charcoal participation decision. However, this may not always hold due to the potential correlation between agricultural productivity and other unobserved factors that are also correlated with participation. The next section attempts to explain how and why agricultural productivity might be endogenous.

In this study agricultural productivity is measured using maize yield. We focus on maize because it is the dominant staple crop not only in Zambia, but also in sub-Saharan Africa, grown by the vast majority of households. In Zambia, maize has been a target of agricultural policies aimed at increasing agricultural productivity and food security in the country.

### *Charcoal participation decision and agricultural productivity*

A few studies that attempt to relate agriculture and wood fuel production and/or sale assume that agricultural productivity is exogenous to the woodfuel participation decision (e.g., Fisher, 2004; Khundi et al., 2011; Mulenga et al., 2014). In reality, the assumption of exogeneity may not reflect how decisions are made. For example, it is not hard to see that increasing urban demand for charcoal coupled with rising charcoal prices creates incentives for smallholder households to participate in charcoal production, and in the long run would shift some of their labor and other resources toward charcoal production, hence reducing available resources for agricultural production. The result is a spurious correlation between participation in charcoal production and agricultural productivity. Furthermore, evidence show that localized deforestation around urban centers as a result of charcoal production, undermines production of ecosystem services, and agricultural productivity (Luoga et al., 2000; Arnold et al., 2006; Kambewa et al., 2007; Alem et al., 2010; Zulu and Richardson, 2013). The declining agricultural productivity would in turn compel farmers to participate in charcoal production in order to supplement agricultural incomes[2] (Mwitwa and Makano, 2012). Under such circumstances, agricultural productivity and participation in charcoal production are jointly determined, making it difficult to distinguish the effect of agricultural productivity on participation since participation in charcoal production may also affect agricultural productivity. The spurious correlation and joint determination of agricultural productivity and charcoal participation makes agricultural productivity potentially endogenous. Failure to control for endogeneity of agricultural productivity makes it difficult to distinguish the effect of agricultural productivity from confounding factors such as charcoal demand, and environmental degradation such as soil erosion.

## Estimation procedure and identification strategy

Our empirical model is based on the standard probit regression model, where the dependent variable (household participation in charcoal/firewood production) takes on a value of one (1) if a household participated and zero otherwise. Two standard binary response models that are typically used are logit and probit. Linear probability model (LPM) which is fitted by ordinary least squares (OLS) is also used sometimes but it suffers some limitations which include: (i) the fitted probabilities can be less than zero or greater than one; and (ii) the partial effect of any explanatory variable is constant (Wooldridge, 2008). In standard binary outcome models, the conditional probability takes the form

$$Pr(y_i = 1|X) = F(X'_i\beta) \tag{1}$$

where $Pr$ is the probability of the binary outcome $y_i$, which is dependent on a vector of exogenous explanatory variables $X_i$; $\beta$s are the unknown parameters to be estimated. The predicted probability falls between zero and one ($0 \le Pr \le 1$) and $F(\cdot)$ is a specified parametric function form for $X'_i\beta$. The two models (logit and probit) are similar except that they assume different functional forms. A logit model assumes a logistic distribution specified as $F(\cdot) = \Lambda(\cdot)$ while a probit model assumes a standard normal distribution specified as $F(\cdot) = \Phi(\cdot)$ (Wooldridge, 2008). Since both models are non-linear the estimated coefficients cannot be interpreted like linear models therefore partial effects are estimated. The two models are estimated using maximum likelihood estimation (MLE) given their non-linearity. For this study a probit model is chosen mainly because of its convenience in computing marginal effects. More specifically, our base empirical probit model is expressed as

$$\begin{aligned}\Pr(charc = 1) &= \beta_0 + \beta_1\ Gen + \beta_2 Age + \beta_3 Edu + \beta_4\ AdultsM \\ &+ \beta_5 AdultF + \beta_6\ Asset + \beta_7\ Inc + \beta_8 Incsq + \beta_9\ Land + \beta_{10}\ Yield \\ &+ \beta_{11}\ off-farm + \beta_{12}\ MktDis + \beta_{13}\ Prov + \varepsilon_i \end{aligned} \tag{2}$$

where the dependent variable (*charc*) is the household's decision whether to participate in charcoal production, taking the value of 1 if the household participated and 0 otherwise. Table 1 defines the explanatory variables used in the model.

However, a priori we expect maize yield to be correlated with the error term and participation, hence endogenous. Generally, the problem here is agricultural productivity could be correlated with some unobserved variables such as charcoal demand and soil degradation (which are captured in the error term), and these same unobserved variables could be influencing the participation decision. Hence, the effect of agricultural productivity on participation

[1] We refer to charcoal production and/or sale as simply charcoal production, as almost all households that reported selling charcoal in our sample produced the charcoal.

[2] It is possible that farm incomes may fall due to declining maize prices and not productivity. However, we assume that maize prices are constant as most all the maize in Zambia is purchased by the government agency (Food Reserve Agency) at a nationally set price, usually higher than market prices.