Agricultural Systems 154 (2017) 168–178

Contents lists available at ScienceDirect

Agricultural Systems

journal homepage: www.elsevier.com/locate/agsy

Agricultural household effects of fertilizer price changes for smallholder farmers in central Malawi

Adam M. Komarek[a,*], Sophie Drogue[b], Roza Chenoune[c], James Hawkins[a], Siwa Msangi[a], Hatem Belhouchette[c,d], Guillermo Flichman[a]

[a] International Food Policy Research Institute, Washington, DC, USA
[b] INRA, UMR 1110 MOISA, F-34000 Montpellier, France
[c] CIHEAM-IAMM, 3191 Route de Mende, 34093 Montpellier, France
[d] UMR System-1123, 2 Place Viala, 34060 Montpellier, France

ARTICLE INFO

Keywords:
Benefit-cost ratio
Bioeconomic model
Cropping systems
Economics
Land use

ABSTRACT

This simulation study explored the agricultural household effects of changes in the price of inorganic nitrogen fertilizer for farmers in central Malawi. We selected the Dedza district to conduct this study, which is a district reliant on maize production for household livelihoods. This study used data from a household survey to develop and calibrate an agricultural household model for a representative household. The survey focused on socio-economic and agronomic factors. This included plot-level agronomic details for crop inputs and yields. Using our dynamic model, we found a negative association between fertilizer prices and fertilizer use, maize area, and income. Removing fertilizer prices led to an increased use of nitrogen fertilizer at the household scale from 16.8 kg to 49.6 kg and this helped increase household income by 52%. We calculated an average own-price elasticity of fertilizer demand of − 0.92. Although higher fertilizer prices increased legume acreage, which had potential environmental benefits, household income fell. Our benefit-cost ratio calculations suggest that government actions that deliver changes in fertilizer prices are relatively cost effective. Our study highlights the reliance of households on maize production and consumption for their livelihood, and the effects that changes in fertilizer prices can have upon them.

1. Introduction

Governments in Africa south of the Sahara often pursue policies aimed at increasing food security and social welfare. One component of these policies includes subsidizing the purchase of inorganic nitrogen fertilizer. Despite these policy efforts, some countries in Africa south of the Sahara have recently experienced declining productivity of staple crops (Jayne et al., 2006; Tittonell and Giller, 2013), especially maize (*Zea mays*). Jayne et al. (2006) suggest the low use of external inputs as a contributor to declining productivity in staple crops. Farmers often desire to use more inorganic fertilizers but face cash constraints in purchasing it, as discussed by Duflo et al. (2011) in the example of Kenya. Poor and declining soil fertility presents a constraint to increasing the agricultural productivity of smallholder, maize-based farmers in Africa south of the Sahara (Place et al., 2003; Jayne and Rashid, 2013; Kihara et al., 2016). In this context, the improved management of nitrogen in cropping systems can help address challenges of sustainable food security and depends on both technological innovation and socio-economic factors (Zhang et al., 2015). Multiple options exist to improve the management of nitrogen in cropping systems including applying inorganic nitrogen fertilizer, growing legumes, applying manure to fields, and retaining crop residues in the field. These options have advantages and constraints, especially the use of fertilizer.

Our study examined the household effects of changes in the fertilizer subsidy component of Malawi's Farm Input Subsidy Program (FISP). The FISP aims to increase maize production, promote household food security, and enhance rural incomes. Beneficiaries of the FISP receive subsidized fertilizer and seed. Lunduka et al. (2013) found that most household-scale studies of the FISP used statistical approaches to show that the FISP generates relatively modest increases in maize production and yields. Earlier studies calculated the benefit-cost ratio (BCR) of fertilizer use. The BCR measures the change in income or value of maize production in relation to the (public) cost of fertilizer use under the subsidy. With the benefit-cost ratio (BCR) ranging from close to zero to over 10, conditional on local context, fertilizer response rates,

---

[*] Corresponding author.
undefinedundefined
URL: http://orcid.org/0000-0001-5676-3005 (A.M. Komarek).

http://dx.doi.org/10.1016/j.agsy.2017.03.016
Received 7 September 2016; Received in revised form 20 March 2017; Accepted 21 March 2017

relative prices, and study method (Dorward and Chirwa, 2011; Chirwa and Dorward, 2013; Lunduka et al., 2013; Arndt et al., 2015). Using a computational, economy-wide market model, Arndt et al. (2015) found that fertilizer response rates were the major factor determining the BCR of the FISP, with a BCR of approximately 1 or 1.62, depending on the calculation used. Ricker-Gilbert et al. (2014) showed that higher fertilizer prices reduced fertilizer demand. Holden and Lunduka (2012) showed that a 1% increase in fertilizer prices increased in the probability of manure use by approximately 0.5%. Chibwana et al. (2012) showed a positive association between household participation in the FISP and maize acreage, and that program participation reduced legume acreage. In Ethiopia, Louhichi et al. (2016) used a computational household model to show that changes in simulated fertilizer prices had a limited effect on crop production and household income. Taking into consideration this literature above, this study asked two questions:

- What are the agricultural household effects of changes in the price of inorganic nitrogen fertilizer for smallholder farmers in central Malawi?
- What are the benefit-cost ratios associated with fertilizer price support?

To answer these questions, we used a mathematical programming model of an agricultural household. The main effects considered were fertilizer use, land use, agricultural productivity, food consumption, and income. Our approach integrated economic and biophysical concepts and data; this included accounting for changes in nitrogen available to crops due to changes in crop management over time and hence any feedback effect this has on household indicators. Our approach complements the statistical and economy-wide studies of Malawi's FISP mentioned above to show BCRs from the alternative perspective of using a farm-household simulation approach. Our approach traces out the linkages between changes in fertilizer prices and its income effects. Our study complements Snapp et al. (2010) and Smith et al. (2016) who analyse partial profitability and grain balances related to the use of fertilizers in Malawi by providing a farm-household perspective on the effects of fertilizer price changes on different indicators of household performance and welfare.

2. Methods

2.1. Characterization of the case study

We conducted this study in the Dedza district of central Malawi. Households in this district are maize-focused, smallholder farmers. We characterized these households by using data collected as part of a participatory agricultural research for development program called Africa Research In Sustainable Intensification for the Next Generation (Africa RISING). The Malawi Africa RISING Baseline Evaluation Survey provided the household data. The survey design involved a stratified random sample, with stratification based on capturing diversity in agroecological potential and then a random selection of households within the diverse villages (IFPRI, 2015). The survey was conducted in the summer of 2013. The survey interviewed 550 households in the Dedza district. The survey collected baseline household data on, among others, crop management including area cultivated and inputs used, grain yields, livestock numbers, family demographics, off-farm income, human food consumption, and prices and costs of all inputs and outputs in the model. The agricultural production data referred to the cropping season October 2012 to May 2013. We divided the surveyed households into three types using Principal Component Analysis and subsequent Hierarchical Cluster Analysis. Our study followed the approach suggested by Norman et al. (1995) and used by Chenoune et al. (2016) for developing household types. This included considering three groups of factors: household resource endowments, production goals, and production intensification. We selected 10 variables related to the three groups of factors that capture household livelihoods and expected ability to respond to changes in fertilizer prices, for example, off-farm income, fertilizer use, and farm size. We retained four principal components that had an eigenvalue greater than one. These components explained 68% of total variability in the original data. We used these principal components in a Hierarchical Cluster Analysis that resulted in us identifying three types of households. We examined the household type that covered 72% of the surveyed households, 395 households from the 550 households. We used data on the mean survey characteristics for this type of household to calibrate our model. We call this household a “representative household”.

Table 1
Characteristics of the representative household simulated in this study.

Characteristics	Units	Mean	Coefficient of variation
Arable land	ha	0.6	0.03
Land planted to legumes	% of arable total	42	0.26
Maize grain yield	$t\ ha^{-1}$	1.8	0.65
Fertilizer applied to maize	$kg\ [N]\ ha^{-1}$	51	0.9
Household size	total number people	4.8	0.77
Off-farm income	$US\ \$\ year^{-1}$	155	1.35

Notes: Coefficient of variation is the standard deviation divided by mean, based on spatial variation among surveyed households. At the time of study, 1 US $ = 364 Malawian Kwacha (MWK). [N] represents nitrogen.

Table 1 shows the arable land, the percent of land planted to legumes, maize grain yield, inorganic nitrogen fertilizer (hereafter referred to as fertilizer) quantities applied to maize, household size, and off-farm income for the household during the summer of 2012 to 2013. Our data appear broadly representative of farming systems in Malawi. Household maize yields averaged 1.8 $t\ ha^{-1}$ and were generally below the average yield for Malawi of 2.1 $t\ ha^{-1}$ in 2013 (FAO, 2016), although yields in Malawi display a wide range. For example, Tamene et al. (2016) report yields in Dedza range from 0.4 $t\ ha^{-1}$ to 12 $t\ ha^{-1}$ and range from 0.8 $t\ ha^{-1}$ to 2.65 $t\ ha^{-1}$ for the national average. The average household applied 51 $kg\ [N]\ ha^{-1}$ of fertilizer to maize plots, where [N] represents nitrogen. Sheahan and Barrett (in press) reported 53 $kg\ [N]\ ha^{-1}$ of fertilizer applied to maize among fertilizer users in Malawi. Mungai et al. (2016) reported that farmers in Dedza who used fertilizer applied approximately 61 $kg\ [N]\ ha^{-1}$. This indicates our surveyed fertilizer rates are like rates among other smallholders in Malawi. The average household cultivated approximately 0.6 ha. Maize occupied on average 58% of arable land and legumes occupied the remaining 42%. In 2013, legumes occupied approximately 30% of arable land in Malawi (FAO, 2016). The average household and owned one adult breeder goat, had 4.8 members living on the farm, and generated US $ 155 $year^{-1}$ in off-farm income.

To examine food consumption, we categorized food consumption goods into the groups used by Ecker and Qaim (2011), with the full list of foods in our study listed in the Appendix. The proportion of total calories consumed in our survey coming from cereals was 79%, for pulses was 10%, for fruit and vegetables was 4%, for animals was 3%, and for meal complements was 4%. This compared to 73%, 11%, 3%, 3%, and 9% reported in Ecker and Qaim (2011), who analysed nationally-representative household data from Malawi.

2.2. Modelling approach

We used a Dynamic Agricultural Household SImulation Model (DAHBSIM) to examine the ex-ante effect of changes in the price of fertilizer on different indicators for the household. Indicators included average yearly fertilizer use ($kg\ household^{-1}$), area of maize (ha) and legumes (ha), maize production ($kg\ household^{-1}$), legume production ($kcal\ ha^{-1}$), total income ($US\ \$\ household^{-1}$), and the proportion of