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**FERTILIZER MARKET REFORM AND
THE DETERMINANTS OF FERTILIZER USE
IN BENIN AND MALAWI**

by

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ABRSTRACT

Most countries in sub-Saharan Africa have reduced or eliminated fertilizer subsidies and liberalized input marketing as part of the reform process that began in the early 1980s. The effect on fertilizer prices and use is one of the most frequently mentioned criticisms of liberalization. The effect of these reforms, however, has varied widely across countries. For example, in Benin fertilizer use has increased ten-fold since 1982, while in Malawi it has risen just 30 percent, less than population growth over the period. This paper explores the factors behind these widely different experiences with input market reform. It relies in part on household survey data collected by IFPRI and collaborating institutions in 1998. The two surveys used nationally representative samples of 800-900 farmers and covered a variety of topics.

A Heckman model is used to identify the determinants of fertilizer use. The study finds that fertilizer use is closely related to crop mix and access to inputs on credit, but not to household income. In both countries, farmers growing cash crops are three times as likely to fertilize their maize fields as other farmers. In Benin, 88 percent of the fertilizer purchased by farmers is bought on credit through the integrated cotton marketing system managed by the parastatal SONAPRA. However, almost one third of this fertilizer is diverted to maize and other crops. In Malawi, tobacco is the most important cash crop among smallholders, but less than half the tobacco growers are able to purchase

fertilizers on credit. Maize accounts for about 60 percent of the fertilizer use, compared to less than a third for tobacco. This difference in the tradability of the main crop being fertilized helps explain some of the difference in performance. In Benin, fertilizer use was stimulated by the 1994 devaluation of the CFA franc, while in Malawi real depreciation of the currency has reduced the profitability of fertilizer.

The results demonstrate some of the paths by which cash crop and food crop production may be complementary. This can occur through the residual effect of fertilizer on food crop production, through the alleviation of cash constraints for the purchase of fertilizer, and through the availability of inputs on credit. In Benin, the availability of inputs on credit is facilitated by the SONAPRA monopsony on cotton purchasing, which makes loan recovery easier. Thus, the benefits of export liberalization must be weighed against the risk that it will weaken the enforceability of seasonal agricultural credit, with indirect consequences for food crop productivity.

1. INTRODUCTION

Most countries in sub-Saharan Africa have reduced or eliminated fertilizer subsidies and liberalized input marketing as part of the reform process that began in the early 1980s. The effect of these reforms on fertilizer prices and use is one of the most frequently mentioned criticisms of the agricultural reforms. Fertilizer prices have generally risen as a result of subsidy removal and depreciation of real exchange rates. In addition, the systems for providing agricultural credit have been disrupted in many countries, partly due to financial losses and partly due to reduction in the scope of activities carried out by the state.

The stagnation in rates of fertilizer application on the continent may have adverse implications for agricultural productivity, rural poverty reduction, and soil fertility. These concerns highlight the need for a better understanding of the factors that influence farm-level decisions regarding fertilizer adoption. One of the goals of this paper is to examine the patterns of fertilizer use in Malawi and Benin and to estimate econometrically the determinants of fertilizer use in each country.

The cases of Benin and Malawi illustrate both the similarities and the

diversity of experience with agricultural reform and fertilizer use. Both countries have liberalized agricultural markets, removed explicit subsidies on fertilizer, and undergone major devaluations in the past 15 years. In both countries, state enterprises continue to play a role in agricultural marketing. In Malawi, the Agricultural Development and Marketing Corporation (ADMARC) remains a dominant player in maize marketing and fertilizer distribution, though it competes with private traders. In Benin, the Societé Nationale de Promotion Agricole (SONAPRA) retains a monopoly on cotton marketing and is the dominant supplier of fertilizer, although private companies are involved in cotton ginning and fertilizer distribution.

The experiences of Benin and Malawi with input market reforms have been markedly different, however. In Benin, fertilizer use has increased ten-fold since 1982, while in Malawi it has risen just 30 percent, less than population growth over the period. A second goal of this paper is to identify some factors that may have contributed to the divergent trends in the two countries, drawing implications for other African countries.

The paper is largely based on household survey data collected by the International Food Policy Research Institute (IFPRI) and collaborating institutions in 1998. The two surveys were based on nationally representative samples of 800-900 farmers and covered a variety of topics including plot-level input use,

crop production, marketing, credit, storage, expenditure, sources of income, and perception of changes over recent years (the survey methods are described in more detail in section 3).

We use data from these two surveys to estimate the determinants of fertilizer use. Previous studies of fertilizer demand have used various methods. One approach is to use probit or logit models to predict whether or not a household will use fertilizer. For example, Falusi (1974) used a probit model in a study of fertilizer use in western Nigeria and Green and Ng'ong'ola (1993) applied a logit model to fertilizer data from Malawi. A second approach is to use a Heckman model to predict both the decision to use fertilizer and the quantity applied. This method is used by Croppenstedt and Demeke (1996) in a study of Ethiopian fertilizer demand. Finally, Coady (1995) uses a double-hurdle model which incorporates a probit estimation of access to fertilizer and a tobit model to predict the quantity of fertilizer used. In the absence of good measures of access and based on a belief that the determinants of the adoption decision may differ from the determinants of the quantity used, we adopt the Heckman model (this approach is further explained in section 4).

The paper is organized in five sections. Section 2 discusses the evolution of agricultural policy and trends in fertilizer use in Benin and Malawi. In section 3, we use the results of the IFPRI surveys to examine current patterns in fertilizer

use in each country. Section 4 presents econometric estimation of the

determinants of fertilizer demand in Benin and Malawi using the Heckman model.

 And section 5 provides a summary of the results and draws some conclusions.

2. POLICY EVOLUTION AND FERTILIZER TRENDS

This section describes the sequence of policy reforms in each country as well as aggregate trends in fertilizer use. The motive is to provide background information for the interpretation of the survey results that are presented in the following sections.

AGRICULTURAL POLICY AND FERTILIZER TRENDS IN BENIN

Agriculture represents almost 45 percent of the gross domestic product (GDP) of Benin and 85 percent of official exports, while employing close to three quarters of the population. Maize, cassava, and yams are the main food crops, while cotton is by far the most important export crop. Fertilizer is used primarily on cotton, with smaller amounts being applied to maize, vegetables, and other crops.

From 1972 to 1989, Benin had a revolutionary military government that adopted (starting in 1975) socialist principles. This led to the creation or strengthening of a series of state enterprises to control agricultural trade and domestic marketing. Although food imports were effectively controled, state

enterprises never handled more than a small percentage of domestic food marketing. In 1982, the state-owned Societé Nationale de Promotion Agricole(SONAPRA) was created to replace the mixed Societé Nationale du Coton and given a monopoly in the marketing of cotton and the distribution of agricultural inputs. During the mid-1980s, fertilizer and insecticides were provided to cotton growers at subsidies equal to 35-50 percent of the total cost. By 1988-89, under pressure from international organizations, the input subsidies were phased out.

In 1989, the first of a series of three structural adjustment programs was launched, leading to deregulation of agricultural trade and domestic food marketing. Between 1992-93 and 1997-98, the importation of fertilizer and insecticide was liberalized, with nine private companies importing the bulk of national requirements. Input distribution is still coordinated by SONAPRA, and farmers pay a pan-territorial price for inputs. Imports through this system are duty free (Bidaux *et al*, 1997). In addition to this "primary" market for inputs, small quantities of fertilizer are imported outside the SONAPRA system, paying 20 percent import duty, and some fertilizer is imported illegally from Nigeria.

Other reforms in the agricultural sector include the disolution of state enterprises in charge of food marketing, the elimination of (largely ignored)

official food prices, legalization of six private cotton gins, the restructuring of the agricultural extension service, and a restructuring of the agricultural credit system which had collapsed under the weight of unpaid loans in the late 1980s (Soulé, 1999).

In the area of macroeconomic policy, the CFA[1] franc was devalued 50 percent in January 1994. Largely as a result of this devaluation, the producer price of cotton has, with some lag, doubled, rising from 105 FCFA/kg in 1993 to 225 FCFA/kg in 1997. The price of fertilizer also doubled, though without a lag, rising from 95 FCFA/kg in 1992-93 to 190 FCFA/kg in 1994-95. The price of food crops has also increased, but to a lesser degree. For example, maize prices have increased from 50-70 percent from 1993 to 1995, while the prices of manioc flour and dried yams have risen around 40 percent. Thus, the fertilizer/crop price ratios have remained constant for cotton, but have risen for food crops (ONASA, 1999).

Fertilizer use in Benin has increased over ten-fold since 1982. It grew from less than one thousand tons in 1980 to over ten thousand tons in the mid-1980s, only to drop to three thousand tons by the end of the decade (see Table 1). This

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[1] The CFA franc is the monetary unit of the Communauté Financiere Africaine, including most of the French-speaking countries of west and central Africa. The CFA franc is pegged to the French franc.

decline is associated with the contraction in cotton production due to lower world prices and the removal of fertilizer subsidies in the second half of the decade. The 1990s have seen a resurgence of fertilizer use, which reached 37 thousand tons in 1997.

Two aspects of this growth in fertilizer use deserve mention. First, since 1990, fertilizer use has grown more rapidly than cotton production. This may reflect higher per hectare application rates on cotton, increasing use of fertilizer on other crops, and/or a reduction of fertilizer smuggling from Nigeria following the elimination of fertilizer subsidies in that country.

Second, the growth in fertilizer use appears not to have been greatly affected by the 1994 devaluation of the CFA franc. Presumably, the higher producer prices of cotton were more than enough to offset the doubling of fertilizer prices.

AGRICULTURAL POLICY AND FERTILIZER TRENDS IN MALAWI

In general terms, agriculture plays a similar role in Malawi as it does in Benin. Agriculture represents over 35 percent of GDP in Malawi, generates about 90 percent of export revenues, and employs more than 80 percent of the population. Historically, the agriculture sector was characterized by a dual

structure composed of estate and smallholder farmers. However, this distinction is slowly eroding as more and more smallholder farmers are growing crops such as burley tobacco which could only be grown by estate farms until a few years ago.

The smallholder sub-sector comprises more than two million farm families engaged in subsistence-oriented agriculture. Smallholder farmers cultivate about 4.5 million hectares of land under customary land tenure system, producing about 80 percent of the food and around 10 percent of Malawi's exports. The main food crops grown by small farmers are maize, beans, cassava, sorghum, rice, and groundnuts. Export and cash crops grown by small farmers include tobacco, chili, coffee, cotton, soybeans, and sunflower.

Prior to 1981, input supply and agricultural marketing in Malawi were monopolized by the government. The Agricultural Development and Marketing Corporation (ADMARC), a state enterprise, distributed subsidized inputs to and purchased output from smallholder farmers at guaranteed fixed prices. In 1981, responding to severe external shocks and macro-economic imbalances, Malawi embarked on a series of structural adjustment and stabilization programs supported by donor organizations.

In 1983, following inadequate and late supply of fertilizers by ADMARC, the

Smallholder Fertilizer Revolving Fund (SFRF) was established to procure and distribute fertilizer to smallholder farmers. In 1988, the SFRF was transformed into a trust fund called the Smallholder Farmer Fertilizer Revolving Fund of Malawi (SFFRFM). The SFFRFM distributes fertilizer through ADMARC's large network of depots.

In 1986, Malawi's economy deteriorated due to falling tobacco and tea export prices, severe droughts, and the disruption of transport routes through Mozambique. A new series of World Bank programs and loans were initiated in 1987. In the agricultural sector, smallholder marketing was liberalized for all crops except for cotton and tobacco, although producer prices were still fixed by the Government. In 1990, smallholder farmers were allowed to grow burley tobacco under a quota system. Cotton production and marketing were liberalized in 1991, and tobacco marketing was freed up in 1994. The tobacco quota system was abolished in 1997-98.

In May 1993, a policy was announced to open up smallholder fertilizer markets (both imports and distribution) to the private sector. Fertilizer subsidies were gradually reduced from 11 percent in 1994 to zero in 1995-96. Since April 1995, all input and output prices have been liberalized, although a maize price band is maintained.

Starting in 1995-96, concern about declining agricultural productivity and food security prompted several donors to launch programs to stimulate input use. The Drought Recovery Inputs Program (1995-96) distributed free inputs mainly to smallholders hit by the drought in 1994-95. The Agricultural Productivity Improvement Project (1996-97) provided input on interest-free credit. The Starter Pack Scheme (1998-99) distributed small amounts of fertilizers and seeds to all smallholders to use on about 0.10 ha of land.

Following the liberalization of fertilizer markets in 1995, several local and international companies started to distribute fertilizers in Malawi, including multinationals such as Norsk-Hydro. Since then, however, several firms such as Optichem and Lufina has withdrawn. ADMARC and SFFRFM remain the main suppliers of fertilizer to smallholder farmers.

Because all fertilizers in Malawi are imported, fertilizer prices are highly sensitive to devaluation. The Malawian Kwacha (MK) was devalued several times since 1994, increasing from about 9 MK/US$ to the dollar in 1994 to 45 MK/US$ in 1999. Similarly, the average price of a 50 Kg bag of NPK or urea increased from about 100 MK per 1994-95 to about 800 to 900 MK in 1998-99. Since the consumer price index rose by a factor of 3.5 over this period, the real price of fertilizer more than doubled. The impact of the higher fertilizer price is

exacerbated by the fact that most fertilizer is used on maize, whose relative price (as a non-tradable) falls with devaluation. As shown in Table 2, the fertilizer/maize price ratio has, on average, increased since 1994 and remains above the level of the 1980s.

As a result, fertilizer use has declined from its peak in 1992-93 at 74 thousand mt of nutrients to less than 50 thousand mt in 1994 and 1995. Fertilizer use picked up again in 1995-96 and 1996-97, partially due to the free input and interest-free credit programs. In addition, liberalization of smallholder tobacco production has increased output and fertilizer use in this sector. Smallholder tobacco production increased from less than 20,000 mt in 1991-92 to more than 94,000 mt in 1997-98. Total fertilizer use, however, is still lower than in the early 1990s.

3. PATTERNS IN FERTILIZER USE

This section describes the patterns of fertilizer use in Benin and Malawi, based on IFPRI surveys in 1998. We begin with a brief summary of the methods used to collect the data.

SURVEY METHODS

The surveys of small farmers in Benin and Malawi were carried out as part of a larger study entitled Impact of Agricultural Market Reforms on Smallholder Farmers in Benin and Malawi funded by the German development agency (BMZ) and carried out by the International Food Policy Research Institute (IFPRI) in collaboration with researchers from two universities (University of Hohenheim and Purdue University) and with local institutions in each country. The local institutions are the Laboratoire d'Analyse Regionale et d'expertise Sociale (LARES) in Benin and the Agricultural Policy Research Unit (APRU) of the Bunda College of Agriculture in Malawi.

The questionnaires used in Malawi and Benin were 20-25 pages long and consisted of pre-coded questions. Topics covered include household

characteristics, farmland characteristics, land, crop production, marketing, labo use, purchased inputs, credit, storage, consumption expenditure, assets, and farmer perceptions of changes over the previous five years. The Malawi andBenin questionnaires are quite similar, although there are some differences reflecting production patterns and policy issues specific to each country. In each country, teams of 10-15 enumerators and 2-3 supervisors were trained to carry out the survey. The questionnaires were tested and revised in June-July 1998, and the data collection took place during August-November 1998.

The Benin survey used a two-stage stratified random sample based on household lists from the 1997 Pre-Census of Agriculture as the sampling frame. One hundred villages were selected randomly from department-level village lists, with a minimum of 10 villages per department. Then, nine agricultural households were randomly selected from the household lists for that village. The final sample size was 899 households.

The Malawi survey used a three-stage stratified random sample. First, 40 of the 154 Extension Planning Areas were randomly selected. Second, two villages from each EPA were chosen. Finally, seven male-headed households and three female-headed households were selected from household lists for each village.   The gender stratification was undertaken to ensure adequate representation of female-headed households. In both countries, weighting

factors were calculated and applied when generating the descriptive statistics.

FERTILIZER USE IN BENIN

Based on the 1998 IFPRI-LARES farmer survey, the average farm size is 3.4 hectares. Farms are larger in the less densely populated north, but many farmers in the south are able to grow a second crop, taking advantage of the bi-modal rainfall near the coast. Maize is grown by 88 percent of farm households. Even in the north, no less than three quarters of the farmers grow maize. Cassava, cowpeas, sorghum/millet, and yams are each grown by 40-50 percent of the farm households, though these tend to be more regionally concentrated. Cotton is grown on just 23 percent of the farms, almost all of which are in the three northern-most departments.

Fully one half of all Benin farmers use fertilizer, a high percentage by the standards of sub-Saharan Africa (see Table 3). This percentage, however, varies by region, being 56-74 percent in the three northern departments and less than 20 percent in two of the three coastal departments.

A somewhat surprising result is that fertilizer purchases are more common among poor farmers than among rich farmers: 57 percent among the poorest quintile, compared to 39 percent among the richest (see Table 3). One explanation for this pattern is the finding that a remarkable 88 percent of the

fertilizer purchased by Benin farmers was obtained on credit. The availability of credit relieves the cash constraints faced by low-income farmers.

It is interesting to note that maize is fertilized by 59 percent of cotton growers, but just 18 percent of non-cotton growers. In other words, the use of fertilizer on maize is three times more common among cotton farmers compared to other farmers. This reflects the fact that cotton farmers are able to purchase fertilizer and other inputs on credit from SONAPRA through the local *Groupement Villageois*. According to the survey, 95 percent of the fertilizer purchases by cotton farmers were on credit from GVs, with the cost being deducted from the value of cotton sold by the farmer at harvest.   In contrast, non-cotton growers obtain fertilizers from the extension service and private traders, and just 12 percent of the purchases are on credit.

Fertilizer use also varies substantially by crop (see Table 4). Virtually all of the cotton area (98 percent) is fertilized. By contrast, only one third of the maize area in Benin is fertilized. The proportion is between 10 and 20 percent for vegetables, rice, and peppers.

Cotton farmers account for 85 percent of the volume of fertilizer purchased by small farmers in Benin. Because of the diversion of fertilizer to other crops, cotton *fields* account for just 62 percent of the national volume, while maize accounts for 23 percent. This implies that close to 30 percent of the fertilizer

purchased by cotton farmers is applied to other crops, mainly maize. To

SONAPRA, this diversion of fertilizer is a source of concern, but to farmers it is a

way to obtain fertilizer on good terms for maize production.

FERTILIZER USE IN MALAWI

The results of the IFPRI-APRU survey of 800 smallholder farmers shed

light on the characteristics of farm production in Malawi. According to the survey,

maize is grown by 99 percent of the households. The other most common crops

are groundnuts (47 percent of households), beans (33 percent), and tobacco (22

percent).

As shown in Table 5, approximately 35 percent of the farm household

used fertilizer in 1998. The average rate of fertilizer application is about 39 kg

per ha. More farmers in the North use fertilizers than in the Center or the South

(59 percent versus 39 and 27 percent). Application rates are also higher in the

North than anywhere else. Tobacco growers are three times more likely to apply

fertilizer on maize than non-tobacco growers. This may be due to the cash

income provided by tobacco production or to the reduced transaction costs for

farmers that are already buying fertilizer for tobacco fields.

Fertilizer use varies also by farm size, household income, and gender of

the household head (see Table 5). For example, only 20 percent of farmers with

less than one hectare of maize used fertilizer compared to 37 to 94 percent of farmers that have farms greater than one hectare in size. However, application rates do not seem to be related to farm size. In fact, farms of more than 10 ha apply about a third of the fertilizer quantity per ha than farms under 10 ha. In contrast to Benin, fertilizer use and application rates in Malawi increase with household income. For example, while only 22 percent of the poorest households apply fertilizer, 43 percent of the richest households do so. Also, 40 percent of male-headed households use fertilizer compared to just 25 percent of female-headed households.

Approximately 23 percent of the cropped area in Malawi is fertilized (see Table 6). The use of fertilizer varies with the type of crop planted. For example, 61 percent of the tobacco area is fertilized, compared to 27 percent for maize and 24 percent for vegetables. Given the large area devoted to maize, however, 64 percent of the fertilizer used is applied to maize. Cassava and sweet potatoes are generally not fertilized.

The largest source of fertilizer for smallholders is ADMARC. According to the IFPRI-APRU survey, ADMARC supplies 61 percent of the fertilizer volume purchased by small farmers, while private companies and traders provide 30 percent and other farmers 7 percent. In contrast to Benin, input credit is rare, with 80 percent of the fertilizer being purchased on a cash basis.

4..ECONOMETRIC ANALYSIS OF FERTILIZER DEMAND

In this section, we present the econometric analysis of plot-level fertilizer use, based on data collected by the IFPRI farmer surveys in Benin and Malawi. We begin with a description of the econometric methods and the rationale for the explanatory variables.

ECONOMETRIC METHODS

In the analysis of the data, we wish to examine the factors that affect fertilizer use including household characteristics, prices, and other exogenous variables. Since there are a large number households that do not use fertilizer, the error terms will not be normally distributed and the coefficients estimated by ordinary least squares will be biased. On the other hand, limiting the regression to households that use fertilizer will introduce sample selection bias.

In this study, we use the maximum-likelihood estimation of the Heckman model, as implemented by the statistical software Stata. The Heckman model describes a situation in which a dependent variable, y, is generated by the standard process $y = x\hat{a} + u_1$, except that y and possibly some of the x s are only observed when $P = \ddot{O}(z\acute{a} + u_2) > 0.5$, where $\ddot{O}(.)$ is the cumulative normal

density function, z is a vector of explanatory variables, á is a vector of

coefficients, and u_2 is an error term distributed N(0,1). If, as is often the case, u_1

and u_2 are correlated, estimating these two relationships separately will generate

biased and inconsistent estimates of â. Heckman proposed a two-step

procedure, but computational capacity now allows simultaneous estimation of â,

á, and ñ=cov(u_1,u_2) with maximum likelihood methods. Thus, the Heckman

procedure generates one set of coefficients (á) predicting the probability that a

household will use fertilizer (P) and another set (â) predicting the volume of

fertilizer used (y) provided it uses some.

EXPLANATORY VARIABLES

In a world of certainty, complete markets, and perfect information,

economic theory indicates that input demand will be determined by input prices,

output prices, quasi-fixed factors of production, and variables that influence the

marginal product of the input. In the context of the demand for fertilizer by small-

scale farmers in developing countries, a wider range of variables may be

relevant. First, since crop production is subject to random shocks and farmers

are risk averse, ability to bear risk (measured by income and ownership of

assets) may influence fertilizer use.   Second, due to imperfect credit markets

and cash constraints of small farmers, membership in credit institutions and cash

income may also affect fertilizer demand. Third, since farmers face transaction costs in buying fertilizer, factors such as distance to markets may have an impact on fertilizer demand. And finally, because farmer information is not perfect, education, literacy, and access to extension services may affect fertilizer demand (see Reardon *et al*, 1999).

We group factors that may influence fertilizer demand in six categories: family labor and human capital (which can be considered quasi-fixed factors for small farmers), land characteristics, market prices, factors that affect the marginal product of fertilizer, indicators of access, and indicators of resources. Each is discussed below.

Labor and human capital: Under this category, we include household size and composition, sex and age of the head of household, education, literacy, and ethnicity. Ethnicity may be relevant if cultural norms vary across groups, if it reflects language barriers, if it influences social capital, or if it is correlated with missing geographic variables.

Land: We examine plot size, farm size, the source of water for the plot, and whether or not the plot is owned. We expect the incentives for input use to be lower on sharecropped land because not all of the marginal product of inputs accrues to the farmer. To the extent that fertilizer has benefits after the year of application, renters may also face less incentive to use fertilizer than owners.

We also include regional dummy variables to pick up the effect of missing variables that are linked to location.

Prices: We include the price of fertilizers (a weighted average of the two main types), the major crops that are fertilized (maize and cotton in Benin, maize and tobacco in Malawi), and wages for agricultural labor. To reduce the effect of price variation due to decisions by farmers (such as where to purchase or what type of activities to hire labor for), we use village-level averages for all prices[2]. Land prices were not included because land transactions are too infrequent to provide a reliable idea of the regional variation.

Factors affecting the marginal product of fertilizer: One of the most important variables affecting the marginal product of fertilizer is the crop being fertilized. A farmer's decision whether to grow maize or manioc will influence his decision regarding fertilizer use, because maize is generally more responsive to fertilizer. We include dummy variables for four major crops in each country (cotton, maize, rice, and vegetables in Benin and tobacco, maize, and vegetables in Malawi). Similarly, we include a dummy variable for purchased maize seed since purchased seed is often of a variety that responds better to fertilizer use.

Access: This category includes variables that reduce transaction costs in

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[2] Where village-level transactions were not observed, we move to progressively higher levels of geographic aggregation (the department and nation in Benin, the region and nation in Malawi).

purchasing and using fertilizer. It includes the distance to the place where

fertilizer can be purchased, the distance from the house to the plot, measure of

access to extension services, and membership in various organizations.   We

assume that distance to point of sale affects the decision to purchase fertilizer

but not the quantity.

Resources: Various measures of the resources of the household may

reflect the ability to bear the risk associated with fertilizer use and/or ability to

overcome the cash constraint associated with purchasing fertilizer in the absence

of well-functioning credit markets. Included are the per capita consumption

expenditure (including the value of home production and the rental equivalent of

owner-occupied housing), the amount of income from off-farm sources, and the

number of different types of livestock. Livestock ownership is also associated

with availability of manure, which may act as a complement to fertilizer (by

improving soil texture) or a substitute (as an alternative source of plant nutrients).

DETERMINANTS OF FERTILIZER DEMAND IN BENIN

The econometric estimation of fertilizer demand makes use of a set of 50

explanatory variables, based on the earlier discussion of fertilizer demand in

developing countries. Summary statistics for each variable as well as a brief

description of each are provided in Table 7. We first describe the determinants

of the decision to use fertilizer on a given plot, followed by the determinants of

the quantity used, conditional on positive fertilizer use.

Determinants of the decision to use fertilizer in Benin

The determinants of the decision to use fertilizer are shown in Table 8.

The first column provides the coefficient (á in the selection equation). The

second gives the robust standard error of the coefficient which take into account

the fact that many of the explanatory variables are at the household-level rather

than the plot-level. The third column gives the z-ratio, while the fourth specifies

the probability of obtaining these results if the true value of the coefficient were

zero. The partial effect, in the last column, is the percentage *point* change in the

probability of fertilizer use associated with a one unit increase in the explanatory

variable[3].

Among the variables describing labor and human capital, only household

size is statistically significant. Other things equal, a large household is more

likely to use fertilizer than a small one, suggesting that fertilizer and family labor

are complements in production. Similar results were found by Croppenstedt and

Demeke (1996). This result is understandable given the labor requirements of

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[3] The partial effect of coefficient i is calculated as $á_i ö(z'á)$, where $á_i$ is the coefficient, $ö()$ is the standard normal density function, z is a vector of the explanatory variables evaluated at the means, and á is the vector of coefficients.

fertilizer application, the increased weeding associated with fertilizer use, and the fact that household members are the main source of labor for Benin farmers. The magnitude of the effect, however, is quite small: each additional member raises the probability of using fertilizer just 0.6 percentage points.

It is interesting to note that female-headed farmers are no less likely to use fertilizer than male-headed household, other things equal. It should be noted, however, that the proportion of female-headed households in the sample is relatively small, just 5 percent of the total. None of the education and literacy variables significantly affects the likelihood of using fertilizer. Given the low level of literacy (24 percent among heads of household in the sample), this implies that if learning is important in fertilizer use, it occurs primarily outside the formal education system and through oral rather than written media. Reardon *et al* (1999) suggests that education often influences fertilizer use through crop mix and the use of improved varieties. If the latter are controlled, as they are here, education becomes insignificant.

Ethnicity has a surprisingly strong effect on whether or not a farmer uses fertilizer. A household from the Fon (ethn1) or Nago (ethn3) group is less likely to use fertilizer, while one from the Adja (ethn2) group is more likely relative to other groups. These differences may reflect language barriers, cultural norms, or social capital in obtaining information and/or credit. Ethnic difference may also

reflect agro-climatic variation, since ethnic groups tend to be geographically concentrated in Benin.

Market prices have significant effects on fertilizer use. The coefficient on the fertilizer price indicates that a 10 percent increase in the price of fertilizer would reduce the proportion of fertilized plots by 2 percentage points or 8 percent.[4] A 10 percent increase in the maize price would raise the proportion of fertilized plots by a similar amount. The coefficient on the price of cotton is the wrong sign and statistically significant. Part of the explanation is that there is very little variability in cotton prices: as shown in Table 7, the coefficient of variation is less than 7 percent, the lowest of any of the explanatory variables. Cotton prices are set by the government and are pan-territorial, so price differences reflect variation in quality and informal market channels. Most of the low cotton prices are in Atacora, the most remote department. One hypothesis is that in some areas, farmers perceive that the fertilizer is free and report on the cotton price net of the cost of fertilizer. This would result in both greater fertilizer use and lower reported prices.

The positive and significant effect of agricultural wages on fertilizer use appears to contradict the complementarity between fertilizer and labor mentioned

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[4] A 10 percent increase in fertilizer price would be an increase of 18.2 FCFA/kg. Multiplied by the partial effect (0.0010), we estimate that the probability of using fertilizer would fall by 1.8 percentage points, equivalent to an 8 percent decline.

above. The survey indicates that hired labor is rarely used for fertilization.

Rather the high wage may reflect off-farm employment opportunities which make

it easier for households to relieve the cash constraint to purchase fertilizer.

Land characteristics appear to have important effects on fertilizer use.

The farm size coefficient indicates that, other things equal, small farms are

somewhat more likely to use fertilizer than large ones, though the statistical

significance is weak. This pattern may reflect greater labor use per hectare on

small farms and/or a long-term tendency for farms to become smaller in more

favorable areas: in Benin, farms are smaller and population more dense in the

higher-rainfall south. The probability of fertilizer use is higher on large plots than

small, each additional hectare increasing the odds of using fertilizer by about 3

percentage points (about 10 percent). The reasons for this are not obvious;

there may be some fixed cost to applying fertilizer to a plot, making it less

worthwhile for small plots.

The department dummy variables indicate that there are important

regional effects not being picked up by the other variables. Zou (the excluded

department) and Oueme (dept5) are more likely to use fertilizer than the other

four departments. Zou is the most accessible cotton-growing department, while

Oueme is close to Nigeria, the source of some smuggled fertilizer.

The likelihood of fertilizing an irrigated plot is 27 percentage points greater

than that of fertilizing an unirrigated plot. Not only is water a complement to

fertilizer, but irrigated plots are more likely to be planted with high-value crops

that provide a good return to fertilization.

Crop mix is one of the strongest determinants of whether or not fertilizer is

used on a given plot. Growing cotton on a plot raises the likelihood of applying

fertilizer by 86 percentage points, making fertilization an almost certainty.

Growing maize, rice, or vegetables also significantly increase the likelihood of

using fertilizer, though to a lesser degree. The omitted crops include sorghum,

millet, cassava, sweet potatoes, and legumes that are less often fertilized.

The interaction dummy variable for cotton growers and maize plots

(ctg_mzp) is statistically significant and positive. This means that, other things

equal, a cotton grower is much more likely to fertilize maize than a non-cotton

grower.   More specifically, being a cotton grower raises the probability of

fertilizing a maize plot by 23 percentage points. This effect is probably linked to

1) the availability of fertilizer on credit for cotton growers, 2) the fact that fertilizer

imported for cotton growers is duty-free, and/or 3) the lower transaction costs in

fertilizing maize if fertilizer is already being purchased for cotton. Similar results

have been found among coffee and tea growers in Kenya and tobacco growers

in Zambia (see Hassan and Karanja, 1997 and Jha and Hojjati, 1993).

Farmers buying maize seed are more likely to use fertilizer. This is

expected since purchased seed is often of a high-yielding variety that responds better to fertilizer than do traditional varieties. The connection between adoption of improved maize seed (particularly hybrid maize seed) and adoption of fertilizer has been identified in numerous countries (see Jha and Hojjati, 1993 for Zambia; Nyonka *et al*, 1997 for Tanzania).

None of the measure of access is significant. Membership in a *groupement villageois* (GV) comes closest to statistical significance, but its effect is probably muted by the close correlation between GV membership and cotton production. Extension contact, group membership, and even having a family connection to the village leader were all statistically insignificant. Similarly, distance to the point of sale of fertilizer was not significant, perhaps because the distances are not that great: the average distance is just five kilometers.

Among the resource variables, per capita consumption expenditure is positively related to the odds of fertilizer use. Although the number of livestock were included as measures of ability to meet cash requirements and to bear the risk of fertilizer use, they appear to affect fertilizer demand more as a source of manure. The number of cattle, oxen, and goats is negatively and significantly associated with fertilizer use, perhaps because livestock owners have better access to manure. The size of the effect, however, is not strong, with each additional animal reducing the likelihood of fertilizer use by less than 0.3

percentage points (around 1 percent).

Determinants of the quantity of fertilizer used in Benin

We now turn our attention to the determinants of the quantity of fertilizer used, conditional on fertilizer use. As shown in Table 9, fewer variables have a statistically significant relationship with the *amount* of fertilizer used compared to *whether or not* fertilizer is used. None of the labor, human capital, and market price variables are statistically significant at the 5 percent level. The highest level of education of family members is positive but only weakly signficant (at the 8 percent level).

The strongest determinant of the quantity of fertilizer used is the size of the plot. The results imply that total fertilizer use increases with plot size but at a decreasing rate. In other words, the per hectare application rate declines with plot size. At the means, each additional hectare is associated with an additional 170 kilograms of fertilizer (recall that these figures refer only to those plots that are fertilized).

Conditional on a plot being fertilized, growing cotton on the plot does not increase the application rate and maize and rice cultivation are associated with *lower* application rates. Although crops other than cotton, maize, rice, and vegetables are not often fertilized, when they are, the application rates tend to be

high. This may be due to the effect of herbs, spices, flowers, and other specialty

crops. The interaction dummy indicating a cotton farmer growing maize has a

negative and significant coefficient, suggesting that among maize fields that are

fertilized, those of cotton farmers have lower application rates. One hypothesis is

that this is the result of policies of SONAPRA to discourage   leakage   of

fertilizer to non-cotton fields. Alternatively, some cotton farmers may only be

applying their excess fertilizer to maize, lowering the average below that of non-

cotton farmers who overcome obstacles to fertilize maize.

As in the previous regression, the number of cattle and the number of

oxen have coefficients that are negative and at least weakly significant. The

magnitude of the effect is relatively small, each animal reducing fertilizer use by

less than 1 kg per plot. Bottom-land plots (*bas-fond*), which are generally

marshy, receive higher applications of fertilizer, though irrigated ones do not,

other things equal.

DETERMINANTS OF FERTILIZER DEMAND IN MALAWI

In this sub-section we use a Heckman model to estimate both the

determinants of the probability of using fertilizer and the factors that affect the

amount of fertilizer used in Malawi. Table 10 provides a definition and

descriptive statistics for the explanatory variables used in the Malawi analysis.

Determinants of the decision to use fertilizer in Malawi

Table 11 shows the factors that influence the decision to use fertilizer. Starting with the human capital and household characteristics variables, we notice that only secondary education has a significant effect on the likelihood to use fertilizer. Presumably, higher level of education increases the awareness of farmers about the benefits of fertilizer. Age of the household head, household size, and household composition are all statistically insignificant. Female-headed households may be *more* likely to use fertilizer than male-headed ones, although this effect is only significant at the 8 percent level and the difference in the probability is only 2 percentage points. This suggests that when other factors are controlled for, there is no gender bias against women in fertilizer use.

The land characteristic variables show expected results. Plot size increases the likelihood of using fertilizer. For each 1 hectare increase, the probability of using fertilizer on the plot rises by 12 percent. The coefficient on the squared plot size variable indicates that this effect tampers off as plot size increases. Farm size has no effect on the probability of using fertilizer, which confirms earlier results from the descriptive analysis (see Table 11).

It is not surprising that, as in Benin, ownership of the plot is not a significant factor in fertilizer use. Unlike longer-term investments, most of the

benefits of fertilization can be captured in the year of application. It is, however, somewhat surprising that irrigated plots are no more likely to be fertilized.

The regional dummies suggest that farmers in the North are most likely to apply fertilizer to a given plot, other factors held constant, followed by farmers in the Center and then farmers in the South. This result confirms anecdotal evidence that fertilizer use in the South is more limited.

For the price variables, we have mixed results. As shown in Table 11, the price of fertilizer does not seem to have a significant effect on the probability of using fertilizer. The wage variable and the price of tobacco are also statistically insignificant. The coefficient on tobacco price may be insignificant because there is little variation in the variable. Alternatively, farmers may perceive fertilization of tobacco to be always profitable, so fertilizer demand is limited only by cash and credit constraints. On the other hand, the price of maize is positive and significant. This suggests that farmers base their decision to use fertilizer on the fertilizer-maize price ratio, rather than on the price of fertilizer alone.

Another set of significant variables are the crop mix variables. As shown in Table 11, tobacco, maize and vegetable plots are more likely to receive fertilizer than other plots. Growing tobacco on a plot increases the probability of using fertilizer by 33 percentage points, while a maize or vegetable plot increases this probability by 19 to 20 percentage points compared to other plots. One very

interesting result is that tobacco growers are more likely to apply fertilizer on their maize plots than non-tobacco growers. This result confirms the descriptive analysis which showed that tobacco growers are three times as likely to fertilize their maize plots than non-tobacco producers. Cash derived from tobacco sales provides farmers with additional income to buy fertilizer. It is also possible that the residual of the fertilizer purchased for tobacco production is used on the farmers' maize plot.

Use of purchased seeds for maize are also positively associated with fertilizer use. This is an expected finding because hybrid maize seed, which is purchased on a yearly basis, responds better to fertilizer than retained seed. Purchased tobacco seed, however, is not significant, because there is little variation in the variable (almost all tobacco seeds are purchased). Among the variables that measure access, membership in a credit club or a cooperative seem to increase the likelihood of using fertilizer. Both credit clubs and cooperatives in Malawi increase the access of farmers to group-based credit and to input and output markets. Approximately, 20 percent of the farmers in the IFPRI-APRU survey belonged to a credit club and 5 percent to a cooperative or association (mainly tobacco associations). The number of extension visits shows no significant impact. This result may be due to the fact that there was not much variability among the farmers regarding the number of visits. Most farmers

received between 16 and 18 extension visits per year. The variable that measures the distance to the fertilizer market is not significant. This finding suggests that farmers in remote areas may not be at a disadvantage regarding access to fertilizer.

Table 11 also reveals differences in the probability of using fertilizer among ethnic groups. For example, the Ngoni and the Yawo are more likely to use fertilizer than other groups. However, the magnitude of these differences are less than 7 percentage points. The ethnic variations regarding fertilizer use may be due to cultural practices or other sub-regional and agro-ecological factors that we cannot account for.

Per capita consumption expenditures (a proxy for per capita income) has a positive and significant effect on the probability of fertilizer use. This is expected in Malawi since most fertilizer purchases are cash-based and require a certain amount of cash income. The magnitude of this effect is small however. A ten percent increase in per capita expenditures increases the likelihood of fertilizer use by less than 0.5 percentage points. Non-farm income, however, is not a significant determinant of the choice to use fertilizer. Number of animals, which approximate wealth or the use of manure, are all non-significant, except for number of pigs. Pig farms in Malawi are becoming more common and are an important source of income to farmers. This might raise the ability of farmers to

purchase fertilizer.

Determinants of the quantity of fertilizer used in Malawi

In Table 12, the factors that influence the quantity of fertilizer used per plot are estimated. Most of the variables that are significant determinants of the likelihood of using fertilizer also influence the quantity of fertilizer used.

The estimation results suggest that among the variables that measure human capital and household characteristics, two variables have a positive impact on the quantity of fertilizer used: household size and secondary level education of the household head. Household size is a proxy for amount of family labor available and its positive coefficient (although only significant at the 7 percent level) suggests that family labor complements fertilizer application in crop production. Secondary education of the household head is associated with 76 kg of additional fertilizer per plot. This may reflect better access to information about crop production. The gender or the age of the household head, as well as the composition of the household are all not significant. This means, that conditional on using fertilizer, these household characteristics do not affect the quantity of fertilizer applied.

As in the results from the probit equation, the quantity of fertilizer used seems to be positively associated with plot size but not related to farm size (see

Table 12). This is a common finding in many agricultural systems. The irrigation variable shows the same insignificant impact as on the probability of using fertilizer. On the other hand, plot ownership has a negative effect. This latter result may be spurious as only 4 percent of the households in Malawi did not own their land.

The regional dummies show almost the same trend as for the probability of using fertilizer: fertilizer application rates are lower in the South compared to the North and Central regions.

The price variables in Table 12 again show that the price of fertilizer, the wage rate, and the price of tobacco are not significant, while the maize price is positive and significant. The interpretation of these results follows the same logic discussed earlier.

Like the probability of using fertilizer, fertilizer application rates are linked to the type of crop grown on the plot. For example, compared to other crops, fertilizer use is higher on a maize, tobacco, and vegetable plots. Similarly, if the household grows tobacco it will apply more fertilizer to its maize plot.

Among the access variables, none of the variables are significant except for the credit club membership, which increases the quantity of fertilizer used. While membership in a cooperative had a positive effect on the probability of fertilizer use, it does not seem to be a significant determinant of the quantity of

fertilizer used. There are some ethnic differences in the fertilizer application

rates. The Lomwe and Yawo use larger quantities of fertilizer per plot than other

groups.

Not surprisingly, per capita consumption expenditures not only has a

positive impact on the probability of fertilizer use but also on fertilizer quantity

application (see Table 12). The other resource variables are all insignificant

expect for the number of pigs owned, which as we mentioned earlier, is a

significant source of income for farmers in Malawi.

5. SUMMARY AND CONCLUSIONS

This paper has highlighted both similarities and differences in the patterns of fertilizer demand in Benin and Malawi. As mentioned earlier, both countries have undergone significant reforms to liberalize agricultural production, marketing, and international trade. These reforms include price decontrol, phasing out fertilizer subsidies, large devaluations to adjust the real exchange rate and stimulate tradable goods production, and legalization of private sector participation in crop marketing and international trade. In both countries, however, a state enterprise continues to play a dominant role in crop marketing (cotton in Benin and maize in Malawi) and fertilizer distribution.

According to the IFPRI surveys, in both countries, over 70 percent of the fertilizer is applied to maize and a cash crop (cotton in Benin, tobacco in Malawi). The survey also finds sharp regional differences in the prevalence of fertilizer use in both countries. Bivariate analysis suggests that cash crop farmers are more likely to fertilize their maize plots than other farmers.

In the econometric analysis of plot-level fertilizer use, data from both countries suggest a positive effect of household size on fertilizer use, implying that family labor is a complement to fertilizer. Other things equal, the effect of

household composition, and sex of head of household is weak or insignificant. It is surprising to find that the sex of head of household is insignificant in Malawi given the large differences in the bivariate analysis (see Table 5). Apparently,female-headed household use less fertilizer because of household, farm, and crop mix characteristics (such as growing less tobacco) rather than because of intrinsic differences.

In both countries, fertilizer demand was significantly related to the price of maize, with higher prices being associated with greater fertilizer use. In contrast, the price of the cash crop was either insignificant or the wrong sign in both models. Several hypotheses for this lack of significance were proposed. In Benin, there was little variability in the cotton price. In addition, the patterns of fertilization of cash crops may be more a function of access to cash or credit and official recommendations than to profit-maximizing calculations. Cotton production in Benin and tobacco production in Malawi (among smallholders) have grown rapidly in recent years so farmers may not yet have the experience in evaluating the returns to fertilizer use.

The dummy variables indicating the crops grown in the plot had strong effects on fertilizer use. In both countries, the likelihood of fertilization was much higher for the main cash crop (cotton in Benin, tobacco in Malawi), for maize, and for vegetables. Similarly, the use of purchased maize seed significantly increased the use of fertilizer in both countries.

In both Malawi and Benin, growers of the main cash crop were much more likely to fertilize maize than other farmers. Several factors may account for this relationship. First, the cash income from cotton and tobacco production may relieve the cash constraint, facilitating purchases. Second, buying fertilizer for the cash crop may reduce the transaction cost for fertilizing maize. In Benin, there is a third factor: cotton production provides access to lower-cost inputs on credit.

The most obvious difference between the experience of Benin and Malawi with input market liberalization is that fertilizer demand in Benin has grown rapidly (though not consistently) since the early 1980s, while fertilizer use in Malawi has fallen in per capita terms. This is related to two other important differences between the input delivery systems.

First, in Benin most fertilizer is applied to cotton, while in Malawi most is used on maize. The removal of explicit subsidies on fertilizer would tend to reduce fertilizer use on both crops, but the removal of implicit subsidies in the form of over-valued exchange rates will have a much stronger negative effect on the incentives to fertilize maize. Depreciation of the real exchange rate raises the fertilizer/maize price ratio because fertilizer is a tradable, while maize is largely non-tradable. In contrast, depreciation has little or no effect on the cotton/fertilizer price ratio (provided that marketing margins are constant) because both are tradable. In fact, to the extent that the 1994 devaluation of the

CFA franc has stimulated the production of cotton, it may well have raised the demand for imported fertilizer.

This pattern is not limited to the two countries in question. An examination of the fertilizer trends in African countries reveals that most of the countries with rising fertilizer use are those that apply fertilizer to export crops (largely francophone West Africa). In contrast, the countries with the lowest (or negative) growth in fertilizer use tend to be those applying fertilizer mainly to non-tradable food crops (particularly east and southern Africa).

Second, in Benin, fertilizer and other inputs are available on credit to cotton farmers. According to the IFPRI-LARES survey, fully 88 percent of the fertilizer purchased by farmers in Benin is bought on credit. In sharp contrast, the survey in Malawi indicates that 80 percent of the fertilizer is purchased on a cash basis. The system of input credit in Benin is based on the legal status of SONAPRA as a monopsonist in cotton marketing, which allows it to ensure repayment of input credit at harvest.

This second issue is also one that is relevant elsewhere in Africa. The benefits of export liberalization in terms of reducing marketing margins and providing higher producer prices must be weighed against the risk that it will weaken the enforceability of seasonal agricultural credit. Given the link demonstrated here between cash crop production and fertilization of food crops, this issue has consequences for food crop productivity. Thus, an important

challenge in Benin and elsewhere in Africa is how to preserve the system of input

credit in the context of export market liberalization; or alternatively, how to

achieve the benefits of export liberalization while maintaining the single-buyer

system that facilitates a financially sustainable input credit system.

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Table 1-Trends in fertilizer use and crop production in Benin

Year	Fertilizer use (mt of nutrient)	Seed cotton production (1000 mt)	Maize production (1000 mt)
1980	862		271.3
1981	2,766		287.9
1982	3,100		271.5
1983	5,400		281.9
1984	7,361		378.2
1985	11,494	89.3	434.7
1986	10,819	132.8	378.3
1987	9,469	70.2	277.2
1988	6,914	108.8	423.5
1989	3,300	104.7	421.0
1990	11,003	146.1	410.0
1991	11,817	177.1	431.0
1992	15,325	161.6	459.5
1993	17,238	277.5	493.1
1994	20,715	265.8	603.2
1995	36,000	349.3	563.2
1996	35,000	348.8	556.5
1997	37,040	400.0	
Annual growth			
Before '89	16.1%	4.1%	5.0%
Since '89	35.3%	18.2%	4.1%

Source: FAO data.

Table 2-Trends in smallholder fertilizer use and crop production in Malawi

Year	Fertilizer use (mt of nutrient)	Tobacco production (1000 mt)	Maize production (1000 mt)	Fertilizer/ Maize price ratio
1982-83	43,001	12	1,369	
1983-84	44,774	20	1,398	
1984-85	34,028	21	1,355	
1985-86	37,479	16	1,295	
1986-87	48,403	14	1,201	
1987-88	51,226	9	1,424	
1988-89	54,800	8	1,509	2.59
1989-90	48,000	14	1,343	2.92
1990-91	70,000	19	1,589	3.30
1991-92	73,800	17	657	
1992-93	74,000	27	2,034	4.93
1993-94	21,283	16	819	3.36
1994-95	43,519	35	1,328	4.73
1995-96	58,200	69	1,793	14.30
1996-97	56,800	84	1,226	5.24
1997-98		94	1,534	4.09
1998-99				2.08
1999-2000				2.31
Annual growth				
Before '89-90	1.6%	2.2%	-0.3%	
Since '89-90	2.4%	26.9%	1.7%	

Sources: Government of Malawi; Masters and Fisher, 1999.

Table 3-Fertilizer use across households in Benin

	Percentage of farmers using fertilizer	Average application rate (kg of fertilizer/ha)
National average	49.6	64.8
Region		
Atacora	55.5	43.8
Atlantique	9.7	4.9
Borgou	68.8	75.9
Mono	57.6	117.3
Oueme	18.1	48.0
Zou	74.3	74.0
Sex of head of household		
Male	49.5	65.1
Female	50.4	58.9
Expenditure category		
Poorest quintile	56.8	59.3
2nd quintile	46.9	45.3
3rd quintile	53.2	64.3
4th quintile	51.9	82.4
Richest quintile	39.1	72.6
Farm size (sown area)		
0 - 1 hectares	34.1	114.0
1 - 2 hectares	35.6	50.3
2 - 3 hectares	44.5	47.7
3 - 5 hectares	53.5	60.7
5 - 10 hectares	64.1	57.8
Over 10 hectares	71.5	60.1

Source: 1998 IFPRI-LARES Small Farmer Survey in Benin.
Note: Average application rate includes non-users.

Table 4-Fertilizer use by crop in Benin

Crop	Share of crop area fertilized (percentage)	Allocation of fertilizer among crops (percentage)
Maize	20.2	23.4
Sorghum/millet	4.3	.7
Small millet	2.9	.1
Rice	16.6	.4
Cowpeas	4.3	1.0
Groundnuts	0.3	.1
Manioc	4.3	2.3
Yams	0.8	.0
Tomatoes	15.1	1.9
Okra	8.4	.9
Hot pepper	33.9	2.5
Other vegetables	19.9	1.9
Cotton	99.5	61.4
Other crops	5.5	3.5
Total	24.6	100.0

Source: 1998 IFPRI-LARES National Survey of Small Farmers in Benin.

Table 5-Fertilizer use across households in Malawi

	Percentage of farmers using fertilizer	Average application rate (kg of fertilizer/ha)
National average	35.2	38.9
Region		
North	58.7	68.8
Center	39.5	35.1
South	26.7	36.1
Sex of head of household		
Male	40.3	44.8
Female	25.2	27.4
Expenditure category		
Poorest quintile	22.3	22.1
2nd quintile	37.1	38.7
3rd quintile	37.7	35.1
4th quintile	37.0	49.4
Richest quintile	42.7	51.2
Farm size (sown area)		
0 - 1 hectares	19.8	28.2
1 - 2 hectares	36.7	32.8
2 - 3 hectares	43.1	31.8
3 - 5 hectares	46.8	34.9
5 - 10 hectares	42.1	33.6
Over 10 hectares	94.4	11.2

Source: 1998 IFPRI-APRU National Survey of Small Farmers in Malawi.
Note: Average application rate includes non-users.

Table 6-Fertilizer use by crop in Malawi

Crop	Share of crop area fertilized (percentage)	Allocation of fertilizer among crops (percentage)
Maize	26.6	63.6
Cassava	0.0	6.1
Sweet potato	0.0	2.8
Beans/Pulses	2.0	1.9
Groundnuts	2.2	8.6
Vegetables	24.4	1.9
Tobacco	61.4	7.4
Soybeans	2.1	1.9
Other crops	9.9	5.8
Total	22.7	100.0

Source: 1998 IFPRI-APRU National Survey of Small Farmers in Malawi.

Table 7-Descriptive statistics of variables in Benin fertilizer model

Variable	Mean	Std. Dev.	Minimum	Maximum	Description
qfert	209.963	248.394	2.00	2000.00	Quantity of fertilizer applied to plot (kg)
hhsize	9.818	5.545	1.00	40.00	Size of household
femhead	0.033	0.178	0.00	1.00	Dummy for female headed household
age_head	46.608	13.675	5.00	95.00	Age of head of household
age2	2359.276	1378.746	25.00	9025.00	Age squared
pct0_5	0.192	0.146	0.00	0.75	Pct. of members 0 to 5 years old
pct6_15	0.301	0.170	0.00	0.80	Pct. of members 6 to 15 years old
pctov65	0.030	0.092	0.00	1.00	Pct. of members over 65 years old
lit_head	0.214	0.410	0.00	1.00	Dummy for literate head of household
ed_head	1.561	3.156	0.00	19.00	Years of education of head
lit_oth	0.483	0.500	0.00	1.00	Dummy for another literate member
ed_max	3.912	3.604	0.00	19.00	Maximum yrs of education of members
ethn1	0.181	0.385	0.00	1.00	Dummy for Fon ethnic group
ethn2	0.080	0.271	0.00	1.00	Dummy for Adja ethnic group
ethn3	0.086	0.281	0.00	1.00	Dummy for Nago ethnic group
ethn4	0.176	0.381	0.00	1.00	Dummy for Bariba ethnic group
pfert	182.068	13.751	105.00	215.00	Price index for fertilizer (FCFA/kg)
pcotton	197.075	13.201	102.86	227.27	Price of cotton (FCFA/kg)
pmaize	144.053	38.139	56.14	255.54	Price of maize (FCFA/kg)
wage	687.426	270.767	113.37	1637.28	Wage rate (FCFA/day)
farmsize	6.368	5.578	0.00	42.60	Size of farm (hectares)
plotarea	0.837	0.998	0.00	20.00	Size of plot (hectares)
plotar2	1.698	8.698	0.00	400.00	Size of plot squared
dpt1	0.138	0.345	0.00	1.00	Dummy for Atacora department
dpt2	0.067	0.250	0.00	1.00	Dummy for Atlantique department
dpt3	0.331	0.471	0.00	1.00	Dummy for Borgou department
dpt4	0.095	0.293	0.00	1.00	Dummy for Mono department
dpt5	0.187	0.390	0.00	1.00	Dummy for Oueme department
owner1	0.718	0.450	0.00	1.00	Dummy for plot owned by farmer
irr2	0.011	0.104	0.00	1.00	Dummy for irrigated plot
irr3	0.070	0.255	0.00	1.00	Dummy for bas-fond plot
distplot	3359.935	9623.728	0.00	280000.00	Distance from house to plot (meters)
cotton	0.104	0.306	0.00	1.00	Dummy for cotton plot
maize	0.250	0.433	0.00	1.00	Dummy for maize plot
rice	0.015	0.122	0.00	1.00	Dummy for rice plot
veg	0.130	0.337	0.00	1.00	Dummy for vegetable plot
ctg_mzp	0.087	0.282	0.00	1.00	Dummy for maize plot and cotton grower
mzseed	0.042	0.200	0.00	1.00	Dummy for maize seed buyer
extacc	0.706	0.455	0.00	1.00	Dummy for extension agent in region
extcont	0.212	0.409	0.00	1.00	Number of contacts with extension
gv	0.589	0.492	0.00	1.00	Dummy for GV membership
coop	0.269	0.444	0.00	1.00	Dummy for cooperative membership
tontine	0.546	0.498	0.00	1.00	Dummy for tontine membership
cheflink	0.339	0.473	0.00	1.00	Dummy for connection to vill leader
nfincval	133752	300947	0.00	3600000	Non-farm income (FCFA)
distfert	5.259	5.649	0.03	33.93	Distance to fertilizer seller (km)
expend	103737	540509	0.00	15600000	Expenditure (FCFA/person)
catnum	4.094	19.021	0.00	390.00	Number of cattle
oxnum	1.193	8.155	0.00	185.00	Number of oxen
pignum	0.384	1.977	0.00	21.00	Number of pigs
goatnum	6.683	9.702	0.00	70.00	Number of goats

Source: 1998 IFPRI-LARES National Survey of Small Farmers in Benin.
Note: The statistics for qfert refer to the 1391 plots with fertilizer use, while the statistics for other variables refer to all 6225 plots in the survey

Table 8:-Determinants of decision to use fertilizer in Benin

	Coef.		Robust Std. Err.	z	P>|z|	Partial Effects
hhsize	0.030	***	0.010	2.825	0.005	0.6%
hhsex	-0.076		0.227	-0.334	0.738	-1.6%
age_head	-0.018		0.016	-1.151	0.250	-0.4%
age2	0.000		0.000	0.661	0.509	0.0%
pct0_5	-0.223		0.287	-0.778	0.437	-4.8%
pct6_15	-0.167		0.267	-0.626	0.531	-3.6%
pctov65	0.255		0.389	0.655	0.512	5.5%
lit_head	-0.027		0.193	-0.140	0.888	-0.6%
ed_head	0.025		0.029	0.858	0.391	0.5%
lit_oth	0.122		0.131	0.931	0.352	2.7%
ed_max	0.003		0.020	0.172	0.864	0.1%
ethn1	-0.533	**	0.217	-2.452	0.014	-11.6%
ethn2	0.695	***	0.216	3.215	0.001	15.1%
ethn3	-0.418	**	0.210	-1.989	0.047	-9.1%
ethn4	-0.058		0.135	-0.428	0.669	-1.2%
pfert	-0.006	**	0.003	-2.053	0.040	-0.1%
pcotton	-0.014	***	0.002	-6.194	0.000	-0.3%
pmaize	0.007	***	0.002	3.921	0.000	0.2%
wage	0.001	***	0.000	4.047	0.000	0.0%
farmsize	-0.020	*	0.012	-1.728	0.084	-0.4%
plotarea	0.151	***	0.055	2.736	0.006	3.3%
plotar2	-0.008		0.006	-1.327	0.184	-0.2%
dpt1	-0.511	**	0.240	-2.127	0.033	-11.1%
dpt2	-1.916	***	0.356	-5.377	0.000	-41.6%
dpt3	-0.474	**	0.223	-2.125	0.034	-10.3%
dpt4	-0.755	**	0.300	-2.519	0.012	-16.4%
dpt5	0.022		0.213	0.105	0.916	0.5%
owner1	0.031		0.097	0.318	0.750	0.7%
irr2	1.235	***	0.378	3.266	0.001	26.8%
irr3	-0.263		0.181	-1.455	0.146	-5.7%
distplot	0.000		0.000	-1.590	0.112	0.0%
cotton1	3.944	***	0.153	25.736	0.000	85.6%
maiz1	0.581	***	0.097	5.979	0.000	12.6%
riz1	1.002	***	0.175	5.736	0.000	21.7%
veg1	0.239	***	0.092	2.596	0.009	5.2%
ctg_mzp	1.052	***	0.131	8.048	0.000	22.8%
mzseed	0.255	**	0.124	2.056	0.040	5.5%
extacc	-0.041		0.134	-0.304	0.761	-0.9%
extcont	0.073		0.101	0.722	0.470	1.6%
gv	0.203		0.130	1.568	0.117	4.4%
coop	0.073		0.103	0.706	0.480	1.6%
tontine	0.135		0.092	1.463	0.143	2.9%
cheflink	-0.017		0.087	-0.191	0.849	-0.4%
nfincval	0.000		0.000	1.598	0.110	0.0%
distfert	0.004		0.008	0.444	0.657	0.1%
expend	0.000	***	0.000	2.716	0.007	0.0%
catnum	-0.002	*	0.001	-1.911	0.056	-0.1%
oxnum	-0.007	**	0.003	-2.158	0.031	-0.2%
pignum	0.010		0.018	0.592	0.554	0.2%
goatnum	-0.009	**	0.004	-2.040	0.041	-0.2%
Constant	1.313		0.893	1.471	0.141	28.5%

Source: Probit stage of Heckman analysis of the 1998 IFPRI-LARES National
Survey of Small Farmers.

Table 9-Determinants of quantity of fertilizer used in Benin

	Coefficient		Robust Std Err.	Z	P>|Z|
hhsize	1.401		1.522	0.921	0.357
hhsex	-35.114		22.740	-1.544	0.123
age_head	-0.042		2.295	-0.018	0.985
age2	-0.010		0.022	-0.480	0.631
pct0_5	-28.778		37.862	-0.760	0.447
pct6_15	20.544		40.995	0.501	0.616
pctov65	64.173		80.682	0.795	0.426
lit_head	9.946		28.350	0.351	0.726
ed_head	-3.404		4.267	-0.798	0.425
lit_oth	-16.982		14.525	-1.169	0.242
ed_max	5.079	*	2.909	1.746	0.081
ethn1	-61.952		42.057	-1.473	0.141
ethn2	106.301		77.878	1.365	0.172
ethn3	0.780		40.483	0.019	0.985
ethn4	-21.908		17.471	-1.254	0.210
pfert	-0.005		0.711	-0.007	0.995
pcotton	-0.067		0.282	-0.237	0.813
pmaize	0.090		0.291	0.311	0.756
wage	0.012		0.020	0.570	0.569
farmsize	-1.986		1.541	-1.289	0.198
plotarea	177.304	***	11.807	15.017	0.000
plotar2	-5.551	***	1.816	-3.057	0.002
dpt1	-59.582		45.561	-1.308	0.191
dpt2	193.601	*	115.921	1.670	0.095
dpt3	-27.014		41.967	-0.644	0.520
dpt4	-199.417	**	89.120	-2.238	0.025
dpt5	6.375		42.953	0.148	0.882
owner1	17.475		12.419	1.407	0.159
irr2	125.972		99.391	1.267	0.205
irr3	99.367	***	19.597	5.071	0.000
distplot	0.001		0.001	0.450	0.653
cotton1	-55.003		35.542	-1.548	0.122
maiz1	-35.310	**	15.382	-2.296	0.022
riz1	-111.907	***	32.957	-3.396	0.001
veg1	-20.616		28.880	-0.714	0.475
ctg_mzp	-92.254	***	21.539	-4.283	0.000
mzseed	-22.290		16.369	-1.362	0.173
extacc	26.894		19.849	1.355	0.175
extcont	-3.283		14.753	-0.223	0.824
gv	16.044		22.236	0.722	0.471
coop	-12.174		12.653	-0.962	0.336
tontine	11.431		12.490	0.915	0.360
cheflink	2.898		13.519	0.214	0.830
nfincval	0.000		0.000	-1.204	0.229
expend	0.000	***	0.000	-4.058	0.000
catnum	-0.405	**	0.195	-2.081	0.037
oxnum	-0.533	*	0.298	-1.789	0.074
pignum	11.925		7.568	1.576	0.115
goatnum	0.871		0.574	1.517	0.129
Constant	139.365		159.657	0.873	0.383

Source: Regression stage of Heckman analysis of the 1998 IFPRI-LARES
National Survey of Small Farmers in Benin.

Table 10-Descriptive statistics of variables in Malawi fertilizer model

Variable	Mean	Std. Dev.	Min.	Max.	Description
qfert*	105.858	111.197	1.00	1200.00	Quantity of fertilizer applied to plot (kg)
hhsize	5.356	2.531	1.00	44.00	Size of the household
femhead	0.227	0.419	0.00	1.00	Dummy for female headed household
age	41.352	14.039	18.00	86.00	Age of household head
pct0_5	19.393	18.161	0.00	75.00	Pct. of members 0 to 5 years old
pct6_15	25.383	20.330	0.00	80.00	Pct. of members 6 to 15 years old
pctov65	2.400	10.102	0.00	100.00	Pct. of members over 65 years old
educ1	0.678	0.467	0.00	1.00	Dummy for head has primary education
educ2	0.067	0.251	0.00	1.00	Dummy for head has higher education
ethn1	0.361	0.480	0.00	1.00	Dummy for Chewa ethnic group
ethn2	0.116	0.320	0.00	1.00	Dummy for Ngoni ethnic group
ethn3	0.147	0.354	0.00	1.00	Dummy for Tumbuka ethnic group
ethn4	0.106	0.308	0.00	1.00	Dummy for Lomwe ethnic group
ethn5	0.124	0.330	0.00	1.00	Dummy for Yawo ethnic group
pmaize	4.172	3.188	0.80	35.71	Price of maize (MK/kg)
ptob	16.995	4.993	2.94	32.69	Price of tobacco (MK/kg)
pfert	11.516	12.290	5.86	86.18	Average price of fertilizer (MK/kg)
wage	63.528	49.930	3.00	500.00	Wage rate (MK/day)
plotarea	0.445	0.353	0.00	6.48	Size of plot in hectares
plotar2	0.322	1.184	0.00	41.93	Size of plot in hectares squared
farmsize	2.098	1.486	0.20	11.33	Total farm size in hectares
farmsz2	6.610	13.930	0.04	128.41	Total farm size in hectares squared
owner	0.961	0.193	0.00	1.00	Dummy variable for plot ownership
irr	0.070	0.255	0.00	1.00	Dummy variable for irrigated plot
reg2	0.456	0.498	0.00	1.00	Dummy variable for Central region
reg3	0.289	0.453	0.00	1.00	Dummy variable for Southern region
tob	0.086	0.280	0.00	1.00	Dummy variable for tobacco plot
maize	0.447	0.497	0.00	1.00	Dummy variable for maize plot
veg	0.042	0.201	0.00	1.00	Dummy variable for vegetable plot
tbg_mzp	0.117	0.321	0.00	1.00	Dummy for maize plot and tobacco grower
mzseed	0.623	0.485	0.00	1.00	Dummy for maize seed buyer
tbseed	0.192	0.394	0.00	1.00	Dummy for tobacco seed buyer
extvisit	17.533	15.014	0.00	60.00	Number of contacts with extension
club	0.277	0.447	0.00	1.00	Dummy club membership
coop	0.100	0.300	0.00	1.00	Dummy cooperative membership
distfert	7.463	5.423	0.40	33.63	Distance to fertilizer seller (km)
expend	3268.603	2881.804	59.00	25567.45	Expenditure (MK/person)
nfincval	2101.196	6130.869	0.00	77600.00	Nonfarm income (MK)
catnum	0.534	1.771	0.00	18.00	Number of cattle
goatnum	6.905	8.991	0.00	56.00	Number of goats
pignum	1.970	3.290	0.00	22.00	Number of pigs

Source: 1998 IFPRI-APRU National Survey of Small Farmers in Malawi
Note: The statistics for qfert refer to the 500 plots with positive fertilizer use, while the statistics for the other variables refer to all 2668 plots

Table 11-Determinants of the decision to use fertilizer in Malawi

	Coef.		Robust Std. Err.	Z	P>|Z|	Partial Effect
hhsize	0.023		0.019	1.190	0.234	0.3%
femhead	0.174	*	0.101	1.722	0.085	2.2%
age	0.002		0.004	0.504	0.615	0.0%
pct0_5	-0.002		0.003	-0.807	0.419	-0.0%
pct6_15	0.000		0.002	0.101	0.919	0.0%
pctov65	-0.001		0.004	-0.273	0.785	-0.0%
educ1	0.111		0.100	1.110	0.267	1.4%
educ2	0.517	***	0.167	3.103	0.002	6.6%
ethn1	-0.201		0.175	-1.145	0.252	-2.6%
ethn2	0.396	**	0.158	2.504	0.012	5.1%
ethn3	0.028		0.158	0.174	0.862	0.4%
ethn4	0.287		0.204	1.405	0.160	3.7%
ethn5	0.471	**	0.186	2.524	0.012	6.0%
pmaize	0.026	***	0.007	3.569	0.000	0.3%
ptob	0.006		0.008	0.690	0.490	0.1%
pfert	0.002		0.003	0.556	0.578	0.0%
wage	-0.001		0.001	-1.431	0.152	-0.0%
plotarea	1.256	***	0.329	3.816	0.000	16.1%
plotar2	-0.379	**	0.171	-2.213	0.027	-4.8%
farmsize	-0.062		0.075	-0.824	0.410	-0.8%
farmsz2	0.007		0.006	1.083	0.279	0.1%
owner	-0.270		0.175	-1.545	0.122	-3.5%
irr	-0.107		0.223	-0.482	0.630	-1.4%
reg2	-0.288	*	0.165	-1.738	0.082	-3.7%
reg3	-0.770	***	0.175	-4.403	0.000	-9.9%
tob	2.616	***	0.212	12.341	0.000	33.5%
maize	1.530	***	0.145	10.574	0.000	19.6%
veg	1.563	***	0.279	5.593	0.000	20.0%
tbg_mzp	0.289	**	0.123	2.349	0.019	3.7%
mzseed	0.798	***	0.094	8.468	0.000	10.2%
tbseed	0.022		0.113	0.197	0.844	0.3%
extvisit	0.000		0.002	-0.141	0.888	0.0%
club	0.246	***	0.095	2.575	0.010	3.1%
coop	0.209	*	0.117	1.787	0.074	2.7%
distfert	-0.002		0.006	-0.294	0.769	-0.0%
expend	0.000	***	0.000	3.495	0.000	0.0%
nfincval	0.000		0.000	1.579	0.114	0.0%
catnum	0.025		0.022	1.107	0.268	0.3%
goatnum	0.001		0.005	0.212	0.832	0.0%
pignum	0.038	***	0.011	3.515	0.000	0.5%
Constant	-3.712	***	0.374	-9.932	0.000	-47.5%

Source: Probit stage of Heckman analysis of data from the 1998 IFPRI-APRU
National Survey of Small Farmers in Malawi.

Table 12-Determinants of quantity of fertilizer used in Malawi

	Coef.	Robust Std. Err.	Z	P>|Z|
hhsize	4.298 *	2.354	1.826	0.068
femhead	17.088	13.797	1.239	0.216
age	0.460	0.454	1.013	0.311
pct0_5	-0.511	0.390	-1.310	0.190
pct6_15	-0.096	0.308	-0.310	0.756
pctov65	-0.136	0.471	-0.288	0.773
educ1	17.924	13.678	1.310	0.190
educ2	76.067 ***	25.192	3.019	0.003
ethn1	-37.395	25.635	-1.459	0.145
ethn2	42.159	27.506	1.533	0.125
ethn3	3.542	20.506	0.173	0.863
ethn4	62.616 **	29.825	2.099	0.036
ethn5	76.398 ***	24.288	3.145	0.002
pmaize	3.118 **	1.318	2.367	0.018
ptob	0.746	1.130	0.660	0.509
pfert	0.119	0.386	0.309	0.757
wage	-0.088	0.101	-0.869	0.385
plotarea	196.932 ***	49.445	3.983	0.000
plotar2	-58.737 **	26.113	-2.249	0.024
farmsize	-9.702	10.497	-0.924	0.355
farmsz2	1.199	1.027	1.168	0.243
owner	-54.342 ***	20.788	-2.614	0.009
irr	-21.994	28.166	-0.781	0.435
reg2	-29.979	19.040	-1.574	0.115
reg3	-115.135 ***	28.805	-3.997	0.000
tob	328.368 ***	83.663	3.925	0.000
maize	194.074 ***	53.964	3.596	0.000
veg	200.617 ***	59.143	3.392	0.001
tbg_mzp	35.175 **	17.521	2.008	0.045
mzseed	87.069 ***	25.677	3.391	0.001
tbseed	11.001	12.747	0.863	0.388
extvisit	0.266	0.300	0.887	0.375
club	23.379 *	12.954	1.805	0.071
coop	12.651	16.091	0.786	0.432
expend	5.651E-03 ***	2.032E-03	2.781	0.005
nfincval	1.154E-03	7.290E-04	1.583	0.113
catnum	1.280	3.626	0.353	0.724
goatnum	0.192	0.546	0.351	0.725
pignum	4.970 ***	1.573	3.160	0.002
Constant	-433.953 ***	139.375	-3.114	0.002

Source: Regression stage of Heckman analysis of data from the 1998
IFPRI-APRU National Survey of Small Farmers in Malawi.