ESSAYS ON AFRICAN RURAL DEVELOPMENT AND ENVIRONMENTAL AND NATURAL RESOURCE POLICY

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Abstract: My dissertation consists of three essays in development economics and empirical microeconomics.

The first essay investigates food security in sub-Saharan Africa and spending in agricultural research and development. A two-stage stochastic frontier analysis is carried out, and deviation from the frontier used as a proxy for inefficiency is regressed against country-specific characteristics in the second stage estimation. Countries with abundant natural resources in which the majority of people live in rural areas tend to be associated with food insecurity based on the prevalence of undernourishment and the depth of food deficit. However, when using the average value of food production and the average dietary energy supply adequacy as measures of food insecurity, resource-rich countries as well as the proportion of people living in rural areas tend to be positively associated with food security.

The second essay studies the factors that affect government assistance to agriculture by specifically focusing on the African rural sector. Through policy indicators such as the relative rate of assistance to agriculture, the cash food bias index, and the World Bank trade bias index (from 1955 to 2011), a fixed effect econometric modeling analysis is carried out in order to determine how a country's GDP, rural population share, arable land share, natural resource endowment, and location explain the assistance government provides to agriculture. Results reveal a negative correlation between a country's rural population share and the level of government assistance provided to agriculture. Governments of resource-rich countries, however, adopt policies that favor agriculture when rural population is above 57 per cent.

The third essay examines the determinants of households' adoption of water conservation practices for indoor and outdoor uses in Oklahoma City. Using a unique dataset that combines actual household consumption data and county assessor's data of house market value and characteristics with a survey of household water conservation methods, a logit model is used to predict the likelihood of adoption. Increased education, age, and income all were found to positively affect indoor and outdoor conservation adoption. Neither higher summer consumption during severe drought, nor the perception of prolonged drought increased outdoor conservation adoption, but owning previously conserving Bermuda lawn did increase adoption.

TABLE OF CONTENTS

Chapter Page

LIST OF TABLES

Table Page

LIST OF FIGURES

CHAPTER I

Spending in Agricultural Research and Development (R&D) and Food Security in Sub-Saharan Africa

Abstract

This paper investigates food security in Sub-Saharan Africa by examining the relatively modest amount of spending in agricultural research and development in the continent. It posits that the agricultural sector in African countries is subject to a certain degree of inefficiency. For that reason, deviations from the frontier of stochastic analysis are used as a proxy for inefficiency; these deviations are regressed against country-specific characteristics in a second stage estimation. Countries with abundant natural resources in which the majority of people live in rural areas paradoxically tend to be associated with food insecurity when the prevalence of undernourishment and the depth of food deficit are used as measures of food insecurity. However, when using the average value of food production and the average dietary energy supply adequacy as indicators of food security, resource-rich countries as well as the proportion of people living in rural areas are associated with higher food security.

Introduction

Sub-Saharan Africa is experiencing an acute period of uncertainty over food supply. It is one of the few parts of the world where food security remains a challenge. According to the United Nations Office for the coordination of Humanitarian Affairs (OCHA) food insecurity has increased in Africa specifically in the horn part of the continent where current weather conditions has aggravated fragile situation of rain fed agriculture. As an example, in Ethiopia, according to the Food Security and Nutrition Working Group (FSNWG), persistent drought has left approximately 19.5 million people under critical and emergency food insecurity levels requiring a long-lasting solution to the country general poverty (USAID, 2016). Such a level of widespread hunger and malnutrition in sub-Saharan Africa calls for an implementation of policies supporting the Green Revolution in an attempt to replicate the Asian Green Revolution.

However, as Estudillo and Otsuka (2013) point out, Africa may benefit from the technology that the Asian countries developed and relied upon in increasing the yield of its staple foods, provided it puts in place an adaptive research program tailoring the Asian technologies to the current conditions in Sub-Saharan Africa. It follows that investments in agricultural research and development are critical in stimulating agricultural growth and resolving chronic poverty and food insecurity in Africa. Research shows that the world has been able to produce more food over the past 40 years using limited agricultural land; such increase in productivity is attributed to agricultural research and development (Heisey, 2011). In the case of grain production, yield increases enabled the world to concurrently increase the quantity of food to respond to the doubling of the world population from 3 billion to 6 billion (Johnson, 1963). Investments in agricultural research and development with its direct incidence in agricultural productivity have been a key factor in preventing the Malthusian nightmare (Alston, 2010).

While technological breakthroughs have prevented most chronic hunger and malnutrition in many parts of the world, specifically in Asia with the implementation of the “Green Revolution,” Sub-Saharan Africa remains the food-insecure region in the planet (FAO, 2013). Household food consumption in Sub-Saharan Africa is made up of staple foods that are not traded much at the international level, and tend not to represent a priority in terms of research at the global level. In these countries, which include mainly the lowest income countries in the world, approximately a third of food consumption is met by non-cereal commodities for which investment in research has been limited. Thus, the technological breakthroughs needed for an exponential increase in yield comparable to the level of the Asian countries have not been obtained (Heisey, 2001).

The lack of sufficient funds at the national level to promote agricultural research and support extension activities to transfer the existing and newly developed technologies to farmers has been associated with a decline in per capita food production in Sub-Saharan Africa (Heisey, 2001). The point of this research is to show, using a quantitative approach that there are inefficiencies in the agricultural sector in Sub-Saharan Africa. Specifically, we would like to use spending in agricultural research and development in Sub-Saharan Africa and food security to come up with a descriptive analysis of the inefficiency that characterizes the agricultural sector in Africa by focusing on the potential impact of spending in agricultural research and development (R&D) on food security.

The paper is organized as follows. A review of past research on food security and spending in agricultural research and development is presented in section 1. In section 2, we look at the conceptual background of the paper while section 3 and 4 respectively describe the data and the econometric models, after which an interpretation of the results follows in section 5. We conclude the investigation in section 6.

Literature Review

Examining the issue of food security, Tweeten (1999) argues that reducing food insecurity is linked to poverty reduction, and he goes on to state that a nation must have a “pie” of purchasing power to redistribute among its food-insecure people. Tweeten (1999) notes that food security tends to be understood mainly as access to food. However, he argues that doing so tends to downplay two important dimensions of food security, availability and utilization. Following the rise of per capita global supply of food, the interest in availability as an indicator of food security is diminishing (Tweeten, 1999). The author finds out that a considerable number of people faced food insecurity not because food was unavailable, but for reasons related to lack of buying power, which implies that the lack in financial resources did not allow them to purchase food. Food insecurity was also caused by excessive price, and lack of transfer to the segment of the population who needed it to access food. However, in such cases, higher economic productivity, freer trade or larger stocks, and greater sense of community may help address food insecurity (Tweeten, 1999).

Finally, availability and accessibility do not alleviate food insecurity if people do not utilize food properly because of inadequate nutrition education and food preparation, bad habits, eating disorders, or poor health. Thus, food security involves more than access; it covers utilization by all people at all times of sufficient nutrients for a productive and healthy life (Tweeten, 1999).

Research shows that there is a relationship between food security and variables such as consumption, production, marketing of food and the functioning of factor markets specifically for labor. Governmental and nongovernmental assistance agencies in addition to initial asset and income distributions tend to be linked to food security as well (Barret, 2002).On the updated version of its “impact model” which sought to present the global projections of food supply and demand, the international food policy research institute (IFPRI) concluded that small changes in agricultural and development can be effective in reducing the number of poor and undernourished people around the world (Rosegrant et al. 2001). It is highly likely that agricultural output will increase considerably in the future if African countries spend more in agricultural research and put in place reforms to improve infrastructure and institution (Rosegrant et al. 2001). Unlike developed countries, developing countries spend a much lower proportion of the value of their agricultural output on research and development, and there is a need in food-insecure regions of which sub-Saharan Africa is a part to continue investing in agricultural research and development in order to reduce hunger while protecting the environment (Heisey, 2001). In addition, agricultural research and development stimulates agricultural productivity, which plays a key role in improving food security (Heisey, 2001). Investments in research and development are necessary to prevent a decline of agricultural outputs from pests and other diseases harming agricultural production (Heisey, 2001).

Besides providing greater food security and better nutrition, investments in agricultural research and development improve the quantity and quality of agricultural outputs, and households deriving income from agriculture will experience an increase in revenue (World Bank, 2014). The Consultative Group in Agricultural Research (CGIAR) reports that investing in agricultural research and development reduces extreme poverty (World Bank, 2014).

Constraints over the use of water resource and land makes an increase in productivity an effective means of increasing the supply of agricultural commodities in order to satisfy an endless growth in the demand of agricultural commodities (Pardey et al., 2010). In fact, with the increase in per capita incomes and population growth, the demand for food will be expected to continue increasing; thus, achieving food security will require investments in agricultural research and development, which directly affects agricultural productivity (Pardey et al, 2010). Taking the same direction Alston (2010) argues that an increase in the amount spent on agricultural R&D would lead to reduction in poverty, and brings food security as the number of hungry people would certainly decrease. Agricultural Research and Development makes new technologies available in agriculture and furthermore makes farmers more productive. However, there are some factors that also contribute to changes in productivity such as improvements in input quality, infrastructure, and education (Alston, 2010).

Theory

Sub-Saharan Africa has the highest number of malnourished people in the world; representing approximately 200 million people. These figures reflect the absence of successful strategies in poverty alleviation and food security improvement (Boussard et al., 2006). Food crises take their origin from shocks such as drought, flood, pests, economic downturns or conflict harming the livelihoods of African insecure population (Boussard et al., 2006). Low household income may better explain food insecurity in sub-Saharan Africa, which is also caused by low labor productivity (Broussard et al., 2006). Thus, food insecurity in Sub-Saharan Africa is mainly an "access" problem implying that households do not have the means to pay the prices for imports, which in a context of domestic food deficit may otherwise be a good recourse to reach adequacy in food availability (Broussard et al., 2006).

We notice that for the same amount of spending in agricultural research and development, the outcome in food security differs between some countries; we can directly infer that some countries perform better than others when it relates to food security.

It is acknowledged that differences in endowments between countries may cause investments in agricultural research and development to produce varying results; however, solely from the efficiency stand point, we may argue that some countries are more efficient than others when it comes to food security and agricultural production.

Agricultural research and development (R&D) institutions are the channel through which new and improved technologies occur, which are necessary for agricultural productivity and food security (Beintema and Stads, 2004). Food and nutrition security are dependent on the availability of food, access to food as a result of purchasing power, and the manner in which people use food (von Braun, 2011).

Research shows that spending on agricultural research and development (R&D) strongly promotes growth and reduces poverty. With high rates of return, agricultural research is considered a cost-effective way for government to stimulate agricultural development (Von Braun, 2011; Beintema and Stads, 2004).

However, Sub-Saharan Africa is among the developing regions where investment in agricultural research and development is the lowest. In fact, the continent is expected to invest only $8.0 billion in research between 1997 and 2020 compared with India and China, which are expected to invest respectively $15.6 billion and $14.6 billion during the same period (Rosegrant, et al. 2001). An increase in agricultural productivity is associated with investments in areas such as research and development, rural infrastructure, rural institutions, etc. It is estimated that an investment in agricultural research and development in a range of US$10 billion would significantly increase agricultural output and lift millions of people out of poverty (Von Braun, 2011). Indeed, with an annual growth rate of 1.1 % of agricultural output, 282 million people in sub-Saharan Africa and South Asia would be lifted out of poverty by 2020 (von Braun, Fan et al. 2008).

In this research, we are primarily concerned with establishing a correlation between expenditure in agricultural research and development and food security in Sub-Saharan Africa. Projection of the world population reveals that by year 2050, there would be 11 billion people in the world, and ninety-seven percent of this population increase will come from developing countries in Africa, Asia, and Latin America (Swaminathan, 1995). With the world population’s increase in perspective, global security becomes a challenge for the future in a sense that food production will have to double or triple to meet the needs of an approximately 11 billion people of whom 90 percent will be located in developing countries.

Moreover, the global population 50 years from now will consume twice as much food. With competition over the use of agricultural resources such as limited agricultural land, and water, agricultural research and technological improvements are of paramount importance for ensuring agricultural productivity and providing income for famers and the rural work force (James, 1996).

Data

Datasets on agricultural research expenditures and human resource capacity of low and middle-income countries compiled by the International Food Policy and Research Institute (IFPRI) under the category, Agricultural Science and Technology Indicators (ASTI, 2016). These provide data on African agricultural spending in research and development (R&D). Based on the availability of data, we consider a sample of nine countries that includes Burkina Faso, Ethiopia, Mali, Nigeria, Senegal, South Africa, Togo, Zambia, and Uganda. The data compiled cover the period from 1981 to 2011. The indicator of food security used comes from the United Nations Food and Agriculture Organization (FAO) classification, which considers four dimensions of food security indicators: availability, access, utilization, and stability (FAO, 2016). The indicator of food security that we plan to use in this investigation is composed of the measures: average dietary energy supply adequacy; average value of food production; depth of the food deficit; and the prevalence of undernourishment.

Procedure

An approach based on stochastic frontier analysis will allow us to examine food security and spending in agricultural research and development in sub-Saharan Africa. As Baltas (2005) notes, the frontier methodology has a microeconomic foundation stemming from the concept of the frontier function that provides highest output values for any given level of inputs (Baltas, 2005). Such an approach becomes the basis for measuring performance and establishing standard in numerous economic input-output systems (Baltas, 2005).

At its origin the stochastic frontier model used a production function model expressed as follows (Kumbhakar and Lovell, 2010):

$$y = [f(x, \beta)] \exp(v - u) , \qquad (1)$$

where y is a scalar output, x is a vector of inputs, and β is a vector of technology parameters. There are two components of the error terms,$v \sim N(0, \sigma_V^2)$ and $u \geq 0$; v captures the effects of statistical noise, and u captures the effects of technical inefficiency (Kumbhakar and Knox Lovell, 2010).

If we consider a linear production function, the stochastic frontier model can be written using a matrix form as (Aigner, Knox, Lovell, and Schmidt, 1977),

$$y = X\beta + \varepsilon \qquad (2)$$

where the error structure is $\varepsilon = v + u$.

The specification of the stochastic frontier model involves two economically distinguishable random disturbance: the nonpositive disturbance u_i showing that each firm's output must lie on or below its frontier $[f(x_i; \beta) + v_i]$ (Aigner, Knox Lovell, and Schmidt, 1977). Any deviation from the frontier, as Aigner et al. (1977) note, can be associated with factors under the firm's control, such as technical and economic inefficiency, the will and effort of the producer and his employees, and also factors such as defective and damaged product. It is possible for the frontier to vary randomly across firms and within the same firm as time changes; for this reason the frontier is said to be stochastic, with random disturbance

($v_i \geq 0$ or $v_i \leq 0$) being the product of favorable events but also unfavorable external events such as luck, climate, topography, and machine performance (Aigner et al., 1977).

Assuming that countries are pursuing efficiency in the agricultural sector (there could be other objectives which are not considered here), we consider indicators for food security as the dependent variable while investments in agricultural research and development and the arable land share as the independent variables. A two-stage stochastic frontier model approach is carried out in which efficiencies are estimated in the first stage, and deviation from the frontier is regressed in the second stage against country-specific characteristics vector of explanatory variables (Baltas 2005, Kumbhakar and Knox Lovell, 2000).

The country-specific characteristics are made up of three variables: two dummy variables describe whether the country is resource rich or not and whether the country is landlocked or coastal, and a third variable is the proportion of people living in rural areas. We will refer to Ndulu et al (2007)'s classification of resource rich country, which highlights three conditions to be met in order for a country to be considered as resource rich. The first states that starting in the initial year; current rents from energy minerals and forests exceed 5 percent of Gross National Income (GNI). The second, a forward-moving average of these rents exceeds 10 percent of GNI; and third, the share of primary commodities in exports exceeds 20 percent for at least a 5-year period following the initial year (Ndulu et al., 2007). They also argue that it is important to differentiate between countries whose economies are resource rich, landlocked, or coastal for a better understanding of Africa's economic performance (Ndulu et al, 2007). Whether a country is landlocked is included following Sowell (1994)'s assertion that the diffusion of ideas that enhance well-being and trading with the rest of the world are more expensive for landlocked countries. The proportion of people living in rural areas is included in order to stress a key finding from development economics literature that the existence of poverty is most serious in rural areas (Todaro, 1997), and also the rural sector is associated with inertia and stagnation which tend to slow down economic growth (Kelley and McGreevy, 1994). In our sample: Nigeria, South Africa and Zambia are considered as resource-rich countries while Burkina Faso, Ethiopia, Mali, Zambia, and Uganda are the landlocked countries.

The dependent variable in the first-stage estimation is the prevalence of undernourishment. It is defined as: “the probability that a randomly selected individual from the population consumes an amount of calories that is sufficient to cover her/his energy requirement for an active and healthy life” (FAO, 2016) and the independent variables are the spending in agricultural research per million population and arable land share in country i in year t.

In this particular case, the frontier (Fig I-1) traces the level of undernourishment in the subset of countries during the period under investigation, revealing which country at a certain point has the lowest level of undernourishment with the amount of financial resources allocated to agricultural research and development.

Following Baltas (2005), the second stage estimation may be described as a frontier response function at the level of individual country characteristics. The empirical response function has a general form (Baltas, 2005):

$$y_i = f(x_i) + \varepsilon_i \qquad (3)$$

where y_i is the dependent variable standing for the deviation from the frontier, x_i is a vector of country specific characteristics affecting the deviation from the frontier, and ε_i is a random term. If we take $\hat{y} = f(x)$ as the baseline function for any combination of country characteristics variables, then equation (3) may be modeled as a frontier function following Kumbhakar and Knox Lovell (2003) stochastic frontier cost model.

The model is expressed as follows: $y_i = f(x_i) + v_i + u_i$ (4)

where v_i is the random variable normally distributed taking into account the estimation noise and non-observed factors that is the stochastic part, while u_i is half-normally distributed random variable reflecting how a given country is found above or below the frontier function (Baltas, 2005).

In addition to using the prevalence of undernourishment as an indicator of food security, we have used three more indicators namely the depth of the food deficit (Fig I-2), the average dietary energy supply adequacy (Fig I-3), and finally the average value of food production (Fig I-4).

Empirical Results

Four models with two-stage estimations were run using the QLIM procedure of the SAS (9.4) statistical package. In the first model the dependent variable depicting food security in sub-Saharan Africa is the prevalence of undernourishment and the independent variables are the spending in agricultural research and development and arable land share in country i in year t.

Model I: The Prevalence of Undernourishment

Results (Table I-3: Model 1) of the econometric estimation of frontier model using the QLIM procedure of SAS (9.4) show that spending in agricultural research and development as well as arable land share are negatively related to the prevalence of undernourishment, with their coefficients entering the model negatively. In fact, for every million dollars' increase for money spent in agricultural research and development, the prevalence of undernourishment decreases by 3.99% while for every percentage increase in arable land share, the prevalence of undernourishment diminishes by 0.19%; both parameters are statistically significant at the 99% confidence level.

In the second stage estimation (Table I-3: Model 1), the deviation from the frontier was regressed against individual country characteristics. These include whether the country is landlocked or coastal, the proportion of people living in the rural area, and resource rich. A dummy variable is used to depict whether a country is resource rich or not. In addition, the interaction variable between resource rich and rural population share is also included as part of the independent variables.

The estimation of the stochastic frontier model in the first stage provides us with a measure of efficiency. The deviation from the frontier is regressed against country characteristic variables. The goal is to come up with an explanation of how factors such as the proportion of people living in rural area affects inefficiency. The fact that a country is resource rich is expected to impact the inefficiency found in the first stage. Finally, the geographical location of the country also influences inefficiency in food security in Sub-Saharan Africa.

The second stage (Table I-3: Model 1) estimation of the deviation from the frontier model where the prevalence of undernourishment was the dependent variable, shows that individual country characteristics involved in the estimation are impacting the deviation from the frontier of the prevalence of undernourishment: being a landlocked country was found to increase the deviation from the frontier. The parameter enters the model positively and is statistically significant at 99% confidence level. Resource rich countries as well as the proportion of people living in rural areas is negatively associated with the deviation, and their respective parameters are statistically significant at 99% confidence level. Unlike countries lacking natural resources, resource rich countries tend to perform better in terms of food security since the deviation from the frontier decreases when a country is resource rich. The same for the proportion of people living in rural area, countries with a considerable size of people in the rural areas tend to have a better food security than country with fewer people in the rural area. When looking at the interaction variable between resource rich and the proportion of people in the rural area it turns out that if a country is resource rich, then as the proportion of people living in the rural area increases the deviation from the frontier of the prevalence of undernourishment also increases. This implies that there are more inefficiencies in resource rich countries than in countries without abundant natural resources. The parameter of the interaction variable enters the model positively and is statistically significant at 99% confidence level.

Model II: The Depth of Food Deficit

In addition to knowing the number of hungry people, actions toward ending hunger would prove to be more effective if we have sufficient knowledge about the depth of their hunger (FAO, 1999). According to the Food and Agricultural Organization of the United Nations (FAO), the depth of food deficit, also known as the depth of hunger, is measured after drawing a comparison between the average level of dietary energy obtained from the foods that undernourished people consume and the minimum amount of dietary energy required to maintain body weight and pursue daily activity (FAO, 1999).

The second model considers the depth of food deficit (Table I-3: Model 2), which expresses how many calories would be needed to lift the undernourished from their status, everything else being equal. The stochastic frontier model used for this purpose considers the depth of food deficit as the dependent variable and seeks to determine how spending in agricultural research and development and the share of arable land affects food security. The outputs reveal that both factors tend to decrease the depth of food deficit with their parameter estimates entering the model negatively and statistically significant at 99% confidence level. For every million spent in agricultural research and development, the depth of food deficit decreases by 34.8% while for every percentage increase in share of arable land the depth of food deficit decreases by 1.8%.

The second stage, (Table I-3: Model 2) estimation of the deviation from the frontier of the depth of food deficit reflects a tendency that geographical location has a great impact on a country's ability to take care of its people. In fact, compared to coastal countries it appears that landlocked country are less food secure as the deviation from the depth of food deficit increases when a country is landlocked. However, having abundant natural resource tends to play a significant role in helping the country to decrease the inefficiency in agriculture since the deviation from the frontier of the depth of food security decreases when a country is resource rich. It follows that because the country is resource rich it is possible that it can easily import food to compensate for food shortage and meet the endless increase in the demand of food locally. The same observation is made for the proportion of people living in rural areas, as the number of rural dwellers increases the deviation from the efficient level of the depth of food deficit tends to decrease as well. However, when using the interaction variable between the proportion of people living in rural area and the dummy variable resource rich, we notice that the parameter estimate becomes positive implying that when a country is resource rich as the number of people living in rural area increases the depth of food deficit also increases.

Model III: The Average Dietary Energy Supply Adequacy

The average dietary energy supply as a percentage of the average dietary energy requirement (ADER) of the country measures capacity of the national food supply in terms of calories, and determines whether undernourishment is mostly explained by insufficient food supply or to bad distribution (FAO, 2013).

The ratio between dietary energy supplied and required is examined in the third model, and will serve as the dependent variable. Spending in agricultural research and the share of arable land will serve as the independent variables in the stochastic frontier analysis during the first stage estimation. The results (Table I-3: Model 3) reveal that for every million dollars spent in agricultural research and development the average dietary energy supply adequacy increases by 2.86 % reflecting positive relationship between the two variables and the parameter estimate is statistically significant at 99% confidence level. Regarding the arable land share, the model estimation shows that for every percentage increase in that variable, the average dietary energy supply adequacy increases by 0.12%, and the parameter estimate enters the model positively with 99% confidence level.

In the second stage (Table I-3: Model 3) estimation in which the deviation from the frontier of the average dietary energy supply adequacy is regressed against country specific characteristics described in the preceding paragraph. Results show that compared to coastal countries, landlocked countries are associated with a decrease in the deviation from the frontier of the average dietary energy supply adequacy. Once again, looking at cost saving perspective there is a strong incentive for landlocked countries to develop agricultural production given their geographical location importing food would be expensive and therefore difficult to sustain. However, when examining the dummy variable resource rich, it shows that countries with abundant natural resources are associated with an increase in the deviation from the frontier. This implies that the level of inefficiency as reflected by the deviation is greater when a country is resource rich.

Other country specific characteristics consider, the proportion of people living in rural area. Results from the second stage estimation show that as the proportion of people living in a rural area increases, the deviation from the frontier also increases. Thus, there is more inefficiency in countries with numerous rural dwellers. It is important to nuance such findings since when taking into account the interaction variable between the proportion of people living in rural area and the dummy variable resource rich, we notice that the parameter estimate enters the model negatively indicating that when a country is resource rich, as the number of rural dwellers increases, the deviation from the frontier decreases, meaning there is more efficiency in a country where the rural population represents the majority provided such country is resource rich.

Model IV: The Average Value of Food Production

As estimated in the New Approaches to the Measurement of Food Security (FAO, 2013), the total value of annual food production, which is expressed in international dollars per caput, reflects a cross-country comparable indicator of the relative economic size of the food production sector in the economy.

The first stage estimation of the stochastic frontier model takes the average value of food production as the dependent variable while spending in agricultural research and arable land are the independent variables. The results (Table I-3: Model 4) show that both variables tend to increase the average value of food production since their parameters enter the model positively and are statistically significant at 99% confidence level. Indeed, for every million dollars spend in agricultural research and development, the average value of food production increases by 13.35 dollars per head ($ per caput) while for every percentage increase in the arable land share the average value of the food production increases by 0.74 dollars per head.

The second stage (Table I-3: Model 4) regresses the deviation from the frontier of the average value of food production against individual country characteristics named above. It follows that compared to coastal countries, being a landlocked country is associated with a decrease in the deviation from the frontier of the average value of food production. The implication is that landlocked countries would benefit more by putting in place efficient means of production of agricultural products than coastal countries as their geographical location will tend to increase the cost of importing foods. The estimate parameter for the dummy landlocked enters the model negatively and is statistically significant at 99% confidence level.

When examining the dummy variable resource-rich country, it is noted that countries with abundant natural resources are associated with an increase in the deviation from the frontier of the indicator of food security, which in this case is the value of food production.

The parameter estimate is positive and statistically significant at 99% confidence level. We may argue that there is a tendency of inefficiency in the agricultural production sector of countries that are endowed with natural resources, which confirms previous research on agricultural distortions in Africa (Bates, and Block, 2009). The proportion of people living in rural areas tend to contribute to the increase in the deviation from the frontier of average value of food production. This implies that countries with considerable rural dwellers tend to be associated with a high level of inefficiency in terms of the value of food production. The parameter estimate positively enters the model and is statistically significant at 99% confidence level.

However, when considering the interaction between the proportion of people living in rural area and resource rich dummy variable, the result shows that for resource rich countries as the number of people living in rural area increases the deviation from the frontier of the average value of food production decreases. In another word, there is a certain level of efficiency in resource rich countries when a non-negligible proportion of the country‘s population lives in rural areas. The parameter estimate of interaction variable enters the model negatively and is statistically significant at 99% confidence level.

Conclusion

This paper has focused on the inefficiency in the agricultural sector in sub-Saharan Africa by investigating how spending in agricultural research and development impacts food security in the continent. With a subset of nine African countries, a two-stage stochastic frontier model is estimated and the results tend to support a correlation between investment in agricultural research and development and food security in Sub-Saharan Africa.

Four indicators of food security are used in this research namely the prevalence of undernourishment, the depth of food security, the average dietary energy supply adequacy, and the average value of food production. Each indicator is a dependent variable in the model estimation while the independent variables in the first stage consist of spending in agricultural research and development per million populations, and the share of arable land in a country considered.

The deviation from the frontier was obtained and regressed in the second stage estimation against country specific characteristics, which consist of two dummy variables “landlocked” implying whether the country is landlocked or coastal, and “resource rich” whether the country has abundant natural resources or not. In addition, the proportion of people living in rural areas was also included and its interaction with the dummy variable “resource rich” included as well. The deviation from the frontier may be interpreted as a measurement of the inefficiency. Results from the second stage estimation tend to show that using the prevalence of undernourishment as the indicator of food security, the deviation from the frontier level of such indicator increases when a country is landlocked. It implies that there tends to be more inefficiencies in preventing undernourishment in landlocked countries than in coastal countries.

However, the level of inefficiency in preventing undernourishment decreases more in a country with abundant natural resources than in countries lacking them. When examining the proportion of people living in rural areas, the estimation shows that it is negatively related to the deviation from the frontier level of the prevalence of undernourishment. Implying that in countries where rural population increases there tends to be less undernourishment. However, the interaction term reflects a tendency that when a country is resource-rich as the proportion of people living in rural areas increases the prevalence of undernourishment also increases. Resource-rich countries likely would tax agriculture less since other major sources of revenue such as mineral or petroleum deposits are available (Bates and Block, 2010). However, what should have been an incentive for rural dwellers to be more productive would be offset by government policies to maintain lower prices of food crops in the urban areas (Thompson, 2008). Thus, disincentivizing rural population to increase the output of food crops, and leaving them vulnerable to chocks resulting in famine or undernourishment.

The second indicator used in our investigation, the depth of food deficit, reflects the number of calories needed to lift the undernourished from their status, everything else being equal. In its report on the state of food insecurity in the world, the Food and Agriculture Organization of the United Nations (FAO, 1999) suggests that Sub-Saharan Africa has the greatest depth of hunger where in forty-six percent of the countries, the undernourished have an average deficit of more than 300 kilocalories per person per day (FAO, 1999). In the second stage estimation of the deviation from the frontier level of depth of food deficit, similar to the prevalence of undernourishment estimation, we find that landlocked as well as the interaction term between resource rich and rural population share enters the model negatively which implies that the depth of food deficit is worse in landlocked countries than in both coastal countries and resource-rich countries with an increasing rural population. However, when “resource-rich country” and “rural population share” enter the model as a single interaction variable, the deviation from the frontier level of the depth of food deficit tends to be negatively related to each variable.

Regarding the average dietary energy supply adequacy as an indicator of food security, the second stage estimation reveals that there is less inefficiency in landlocked countries and also in resource rich countries with an increasing proportion of people living in rural areas. However, similar to the findings in the average value of food production, when “resource-rich country” and “rural population share” enter the model as a single variable, inefficiency as measured by the deviation from the frontier level of the average dietary energy supply adequacy tends to increase.

When looking at the average value of food production’s indicator in the second stage estimation, the deviation from the frontier level of the average value of food production decreases when a country is landlocked, implying that countries without coastline or seaport tend to invest more in efficient means of agricultural food production. The same finding is for the interaction variable between resource rich and rural population share, which also shows that in resource-rich countries, increased rural population is associated with improved food security. However, when entering the model as single variables, “resource rich” as well as “rural population share” tend to correlate with increased inefficiency in food security.

These results could help policy makers and private or public donors prioritize where resources should be allocated to increase their effectiveness in addressing food security in sub-Saharan African countries. However, to have a better understanding of the subject it is imperative to consider expanding the dataset by including more country-characteristic variables, and institutional variables such as property rights, the quality of government, the absence of political corruption, which play an essential role in economic growth and poverty alleviation (Norton, 2003; Todaro, 1997).

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APPENDIX FOR CHAPTER I

Table I-1a. Definitions of Dependent and Independent Variables Used for Regression Estimation

Dependent Variable	Definition
Prevalence of Undernourishment	% of population whose food consumption is not enough to meet dietary energy requirement on a regular basis (Knoema, 2016)
Average Value of Food Production	I$ per person, the food net production value in per capita terms (FAO, 2016)
Average Dietary Energy Supply Adequacy	Dietary energy supply (DES) as a percentage of the average dietary energy requirement (ADER) (FAO, 2016)
Depth of the Food Deficit	Quantity of calories needed to lift the undernourished from their status, everything else being constant expressed in kilocalories per person per day (FAO, 2016)
Independent Variable	**Definition**
Resource Rich Country	If Yes=1, if No=0
Landlocked Country	If Yes=1, if No=0
Rural Population Share	Share of a country's population living in rural areas
Spending in agricultural R&D	Agricultural research expenditure per million population (IFPRI)
Arable Land Share	Share of land area that is arable under permanent crops, and under permanent pastures (World Bank)
Countries	Sub-Saharan African countries
Year	1981 to 2011

Table I-1b. List of countries used in the Regression Estimation

Resource rich Countries	Landlocked Countries
Nigeria	Burkina Faso
South Africa	Ethiopia
Zambia	Mali
	Zambia
	Uganda

Table I-1c: Economy of Countries used in the Regression Estimation

Country	GDP per Sector	Main Labor force occupation	Main Industries
Nigeria	Agriculture 17.8% Industry 25.7% Services 54.6%	Accommodation, food, transportation, and real estate 12.2% Retail, and operations 24.9% Other services 8.8%	Cement, oil refining, construction materials, food processing and food production, and automobile manufacturing
South Africa	Agriculture 2.5% Industry 31.6% Services 65.9%	Agriculture 9% Industry 36% Services 65%	Mining, automobile assembly, metalworking, machinery, and commercial ship repair
Zambia	Agriculture 8.6% Industry 31.3% Services 60%	Agriculture 85% Industry 6% Services 9%	Copper mining and processing, construction, beverages, chemicals, textiles, fertilizer, and horticulture
Burkina Faso	Agriculture 34.4% Industry 23.4% Services 42.2%	Agriculture 90% Industry and services 10%	Cotton , beverages, agricultural processing, soap, cigarettes, textiles, and gold
Ethiopia	Agriculture 40.5% Services 43.3% Industry 16.2%	Agriculture 85% Services 10% Industry 5%	Food processing, beverages, textiles, leather, chemicals, and metals
Mali	Agriculture 45% Industry 17% Services 38%	Agriculture and fishing 80% Industry and services 20%	Food processing, construction, phosphate and gold mining
Uganda	Agriculture 23.1% Industry 26.9% Services 50%	Agriculture 40% Industry 10% Services 50%	Sugar, brewing, tobacco, cotton, textiles, cement, and steel production

Source: CIA World Fact Book, 2015

Table I-1d. Legend

Countries Name	Abbreviation
Nigeria	NGR
South Africa	RSA
Zambia	ZB
Uganda	UGD
Togo	TG
Senegal	SNGL
Mali	MALI
Ethiopia	ETH
Burkina Faso	FASO

Table I-2. Sample Descriptive Statistics

Variable	Definition	N	Mean	Std. Dev.	Min.	Max.
Prevalence of Undernourishment		169	25.54	13.19	5.00	60.60
Average Value of Food Production		169	143.43	48.45	72.00	243.00
Average Dietary Energy Supply Adequacy		169	108.12	12.31	81.00	135.00
Depth of Food Deficit		169	170.56	111.88	24.00	488.00
Spending in Ag R&D per Million Population		169	3.58	2.01	0.85	9.28
Landlocked	If Yes=1, if No=0	169	0.53	0.50	0	1.00
Resource rich	If Yes=1, if No=0	169	0.36	0.48	0	1.00
Rural Population Share	Share of a country's population living in rural areas	169	67.59	13.80	40.70	88.42
Land arable Share	Share of land area that is arable under permanent crops, and under permanent pastures (World Bank)	169	17.98	12.63	1.73	46.15
Country	Sub-Saharan African countries	169				
Year	1981 to 2011	169				

Table I-3. Two-stage estimation of Stochastic Frontier models

	Model 1: Prevalence of Undernourishment		Model 2: Depth of Food Deficit		Model 3: Average Dietary Energy Supply Adequacy		Model 4: Average Value of Food Production	
Variable	Parameter Estimate	Standard Error	Parameter Estimate	Standard Error	Parameter Estimate	Standard Error	Parameter Estimate	Standard Error
Frontier Function (1st stage estimation)								
Intercept	42.16	48.18	324.98	481.46	95.89	125.29	82.69	456.89
Spending in Ag R&D per million population	-3.99***	0.48	-34.81***	3.27	2.87***	0.42	13.35***	1.59
Arable land	-0.20**	0.07	-1.78***	0.51	0.12*	0.07	0.74**	0.25
Regression Function (2nd stage estimation)								
Intercept	4.47	9.62	70.60	74.08	-38.77***	9.50	-238.03***	33.16
Landlocked	8.28**	2.99	84.93***	22.69	-4.49	2.91	-35.84***	10.16
Resource rich	-46.12**	14.57	-259.00**	85.04	50.91***	10.91	270.94***	38.07
Rural Population share	-0.33**	0.15	-3.33**	1.13	0.45**	0.15	3.08***	0.51
Resource rich*Rural Population share	0.17**	0.24	4.44**	1.37	-0.80***	0.18	-3.79***	0.61

Notes: ***=significant at 1% level, **=significant at 5% level, *=significant at 10% level

Fig I-1: The Prevalence of Undernourishment in Sub-Saharan Africa (SSA)

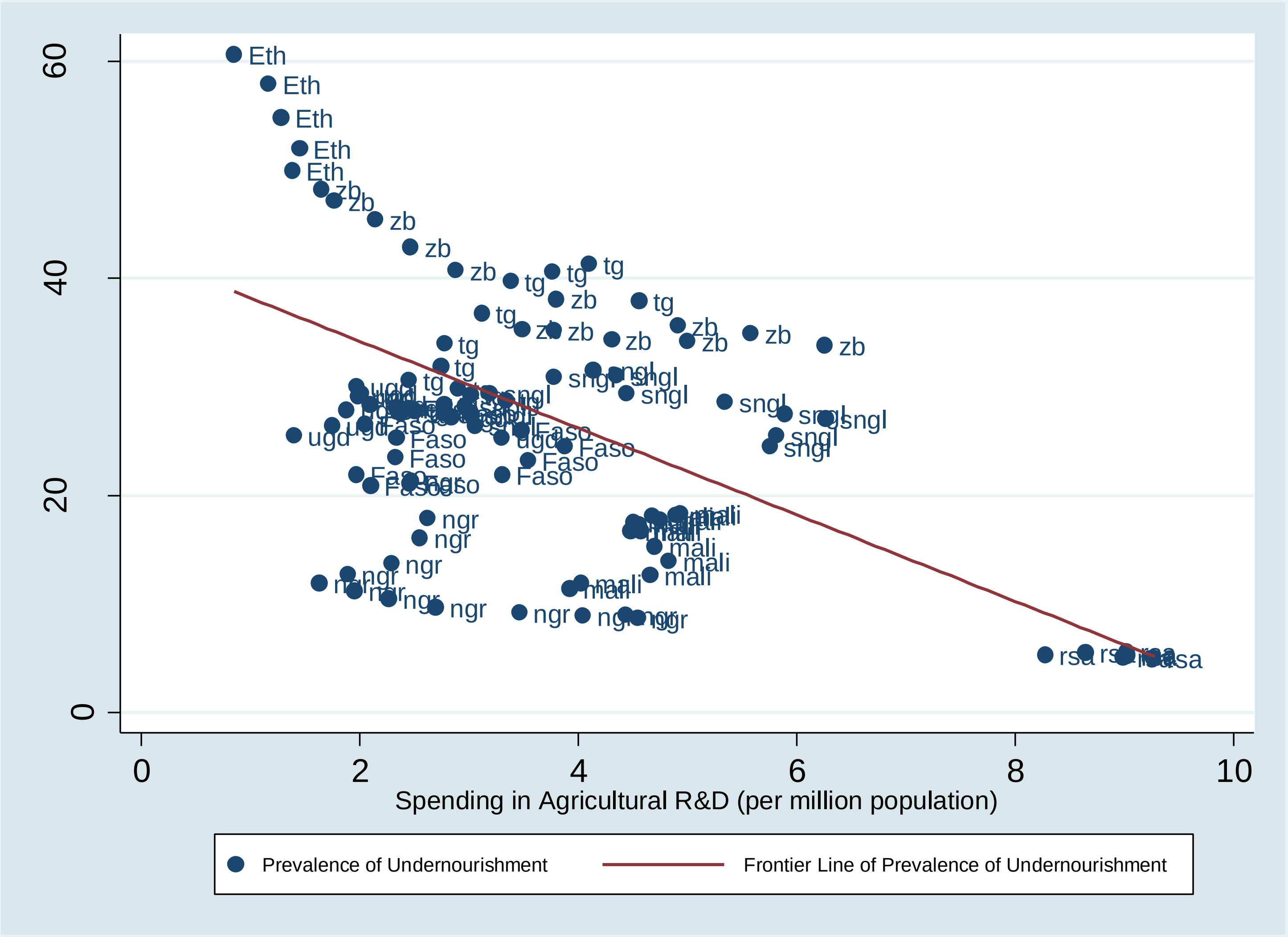


Fig I-2: The Depth of Food Deficit in Sub-Saharan Africa (SSA)

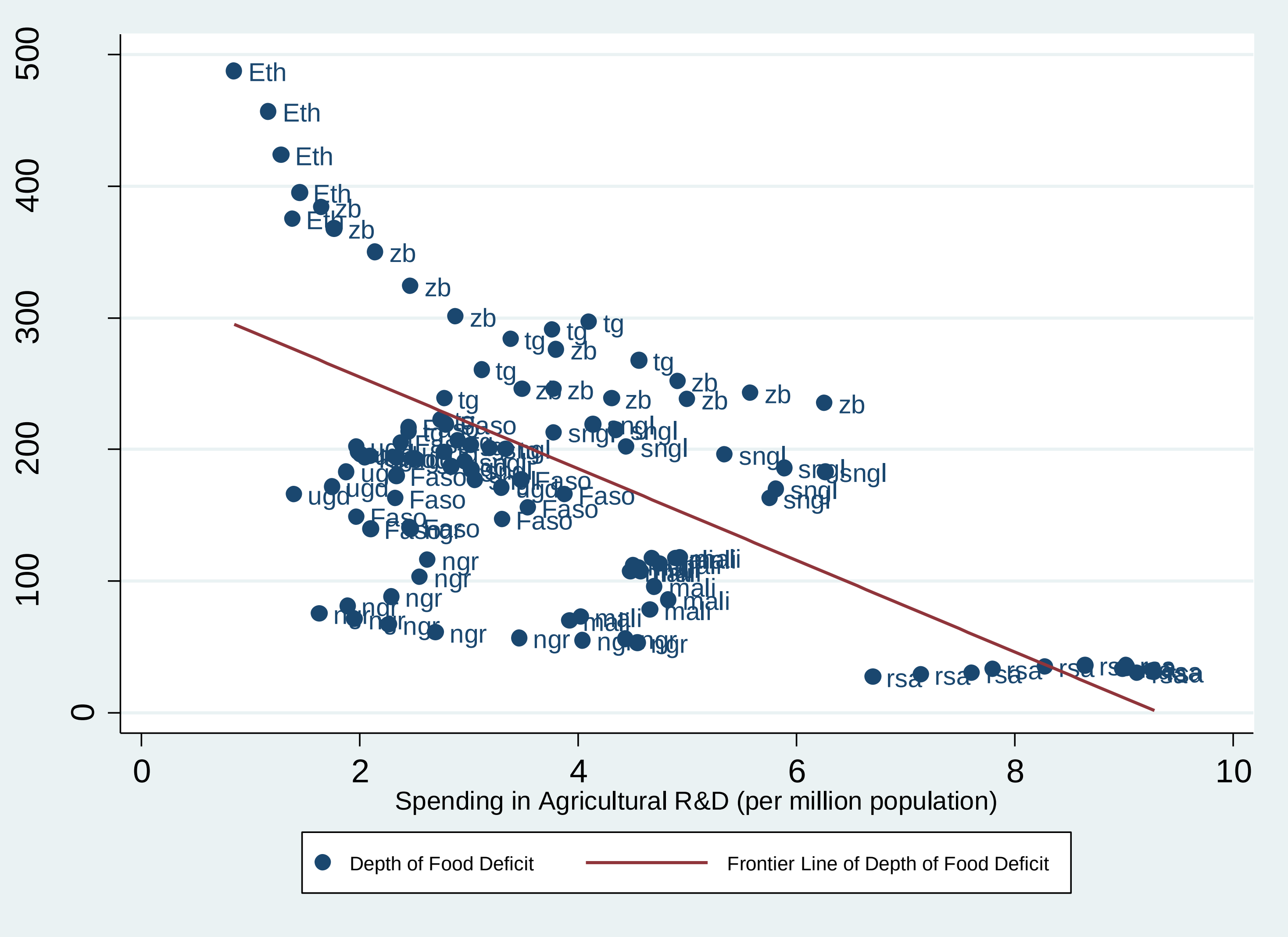
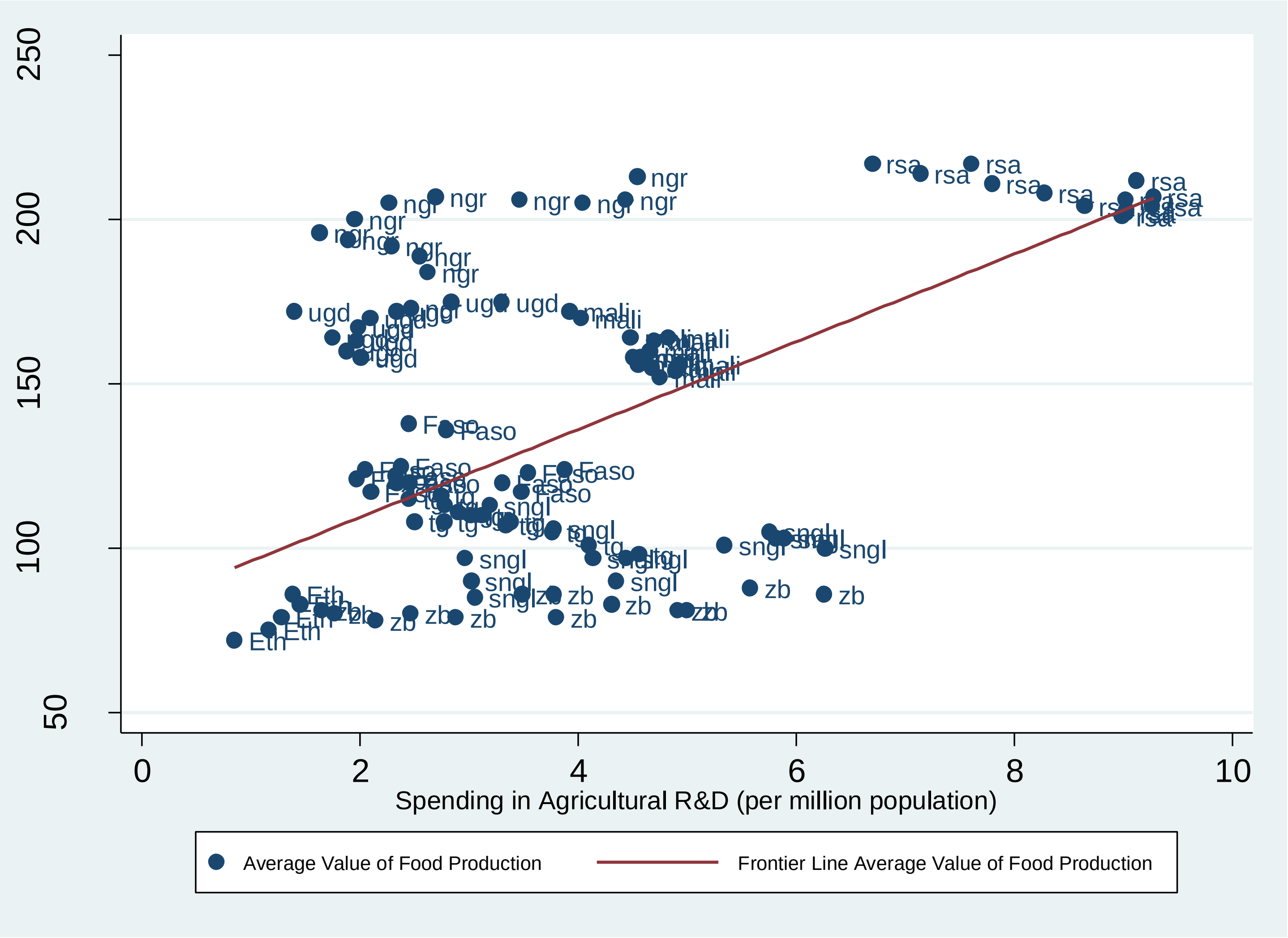


Fig I-3: The Average Dietary Energy Supply Adequacy in Sub-Saharan Africa (SSA)

Fig I-4: The Average Value of Food Production in Sub-Saharan Africa (SSA)



CHAPTER II

Agriculture in Developing Countries and the Role of Government: Economic Perspectives

Abstract

This paper studies the factors that affect government assistance to agriculture by specifically focusing on the African rural sector. Price support schemes have been an important element of agricultural policies in African countries. Through policy indicators such as the relative rate of assistance to agriculture, the cash food bias index, and the World Bank trade bias index from 1955 to 2011, a fixed effects econometric modeling analysis is carried out in order to determine how a country’s GDP, rural population share, arable land share, natural resource endowment, and location explain the assistance government provides to agriculture. The empirical results reveal a negative correlation between a country’s rural population share and level of government assistance provided to agriculture. Governments of resource-rich countries, however, adopt policies that favor agriculture when the proportion of rural population is above 57 per cent.

Introduction

Agriculture has been a critical driver of societal well-being for centuries, ensuring food security and catalyzing productivity needed for economic prosperity (Robin, 2011). Sixty-five percent of Africans rely on agriculture as a primary source of livelihood, and small-scale famers are responsible for ninety percent of agricultural production (IFPRI, 2009). Across the African continent, there has been a renewed commitment from governments, non-governmental organizations, and the private sector to move agriculture from a development challenge to a business opportunity. As a result, countries such as Nigeria are moving to once again become a net exporter, rather than an importer, of agricultural commodities (Robin, 2011). Agriculture is among the most powerful engines for Africa's economies, many of which have experienced rapid growth over the last decade (Robin, 2011). The growth rate of agriculture in Africa has increased from 2.4 per cent in 1980-89 to 2.7 per cent in 1990-99 and 3.3 per cent since 2000 (Diao et al., 2007).

Despite these encouraging developments, many smallholder farmers, who form the backbone of Africa's agriculture sector, remain trapped in poverty without access to financing and other tools to increase their productivity and profitability (Robin, 2011). As Binswanger-Mkhize et al. (2009) and Nwachukwu et al. (2007) point out, over 70 per cent of Africa's poor people live in rural areas and depend on agriculture for a large share of their income, yet, the level of assistance provided to agriculture is diminishing. Compared to developing countries in other parts of the world, African governments' budget allocation to agriculture is small. African countries' spending on agriculture represented 6 to 7 per cent of total national budgets for 1980-05, while in Asia allocations were twice as large, ranging between 6-15 per cent (IFPRI, 2009). According to the

World Bank (2010), 48 per cent of the population in Africa lives in extreme poverty on $1.25 a day, arguing that it is necessary to implement a comprehensive, economic and social development program in the continent. Nwachukwe et al. (2007) notes that this program needs to target poverty alleviation in rural areas since Africa's rural population share accounts for 62.7 % of the total population, and land, and natural resources and mineral resources are mostly located in rural areas (World Bank, 2010).

The purpose of this paper is to explain patterns of government assistance to farmers across various African countries taking into account factors such as rural/urban population share, real GDP per capita, arable land share, etc. This analysis enables the following questions to be addressed. Is government support to agriculture influenced by whether farmers producing cash crops or food crops? Does such level of support vary depending on the rural/urban share of the population?

The paper is organized as follows. A review of past research on the role of government in agriculture is documented in section 1. In section 2, we looked at the conceptual background of the paper while section 3 and 4 respectively describe the data and the econometric models used in the investigation, which are followed by result interpretation in section 5. In the conclusion, in section 6, we note the complexity of the role of government in agriculture and how using price support approach helps to understand agriculture in developing countries specifically in Africa.

Literature Review

Research on the interaction between government and agriculture is well documented. Some researchers argue that political institutions determine the level of governmental assistance to farmers; their argument is based on the logic of collective action (Olson, 1971) which suggests that compared to small groups, large groups will face high costs when trying to organize and therefore the incentive for group action diminishes as group size increases in a sense that large groups are less capable of acting in their common interest than small groups.

Following the same direction, Bates and Block (2009) in their investigation of political economy of agricultural trade protection in Sub-Saharan Africa note that there is a tendency for governments in countries with considerable farmers and where agriculture is the main economic activity to enact policies that do not benefit famers. Instead, governments in these countries tend to impose a heavy tax on farmers. They argue that government policies toward agriculture will tend to be detrimental to farmers the greater "the rural dwellers share of population," depending upon the nature of the party system.

In their investigation toward what causes some nations to prosper and others to fail, Acemoglu and Robinson (2012) simply state that it is a matter of institutions. We may find answers to African rural poverty by looking at the nature of political institutions in place. The hypothesis is that whether a country has extractive political institutions or inclusive economic institutions will play a central role in bringing a country out of poverty and shape the road for prosperity. Acemoglu and Robinson (2012) argue that inclusive economic institutions are more conducive to economic growth than extractive economic institutions, by enforcing property rights, creating a level playing field, and encouraging investments in new technologies and skills. They argue that countries prosper when they put in place comprehensive political and economic institutions, and decline when those institutions only provide opportunities to the politically connected segment of the population (Acemoglu and Robinson, 2012).

When taking into account geographical location, Ndulu et al. (2007) conclude that landlocked countries are likely to show less bias against agriculture trade than coastal states which tend to display the greatest bias. The evidence of natural resource endowment on government agricultural policies has been mixed. Bourguignon and Verdier (2000) suggest that governments of resource-rich countries will tend to exhibit less support for agriculture since the existence of natural resources may prevent redistribution of political power towards the middle classes and thus prevent adoption of growth-promoting policies; and Isham et al (2003) add that resource wealth worsens quality of institution because it allows governments to avoid accountability and resist modernization. In fact, agricultural support can be growth promoting if it enables African small producers to become more competitive, specifically against cheap food imports from abroad (OECD, 2006).

However, Bates and Block (2009) contend that governments of resource-rich countries have a tendency to enact policies that favor producers of both food and cash crops. They argue that governments of resource-rich countries, especially in Africa, have tended to protect food crops, raising the level of domestic prices above those prevailing in world markets, while taxing cash crops (Bates and Block, 2009). When using arable land share as a proxy for the overall importance of agriculture, Bates and Block (2009) find that it is positively related to policy orientation of governments towards agriculture.

Theory

In this research we are primarily concerned with the role government can play in lifting rural farmers from subsistence agriculture to a mass production type of agriculture drawing from the example of Asian countries with the Green Revolution, as it has been shown that strong public support and public interventions through the development of technologies and the building of adequate infrastructures were crucial in ensuring modernization of agriculture and rural farmers poverty alleviation (Diao et al., 2007). Taking a price support approach, this investigation ties the development of the agricultural sectors and African small farmers' wellbeing to the ability of African governments to provide assistance to the rural sector. Price supports to agriculture can take a form of subsidies such as direct input distribution, universal input subsidies and targeted market-smart subsidies that help cash-constrained farmers find a solution to issues regarding risk, uncertainty and lack of well-functioning markets (FAO, Policy Brief N03, 2008). Market-smart subsidies tend to be friendly to private markets, they stimulate demand in private markets, boost entrants, and are targeted at small holders and poor farmers (Banful, 2010).

African countries have tended to adopt policies that favor the interests of urban dwellers by lowering the cost of food, and thus provide protection to urban dwellers that in large part are poor and spend a large portion of their incomes on food (Bates and Block, 2009). African agricultural production depends on small producers scattered throughout the countryside, and as individual producers are unable to influence government policy because organizing so large and diverse a population is expensive consequently in countries with large agricultural populations, agriculture represents an ineffective interest group. On the other hand, when agricultural population is large, urban population would tend to be small and spatially concentrated. Consequently, consumers should hold a relative advantage as lobbyists in countries with large agricultural population (Bates and Block, 2009). Thompson (2008) to add that third world countries specifically African countries regularly implement price controls to maintain food prices artificially low. The reason behind such policy is to gain favor with their political base living in urban areas. However, as Thompson (2008) notes by maintaining a low price of food for urban dwellers, governments ironically disincentives farmers to produce, thus decreasing the availability of food from local sources

While the logic of collective action (Olson, 1971, Bates and Block, 2009) is coherent at explaining the lack of adequate food production systems, poverty and hunger in rural Africa, we are hypothesizing that the levels of assistance farmers receive from government depend mainly on the rural population share and the percentage share of agriculture in the economy. If agriculture represents the main economic activity the government level of assistance to farmers will tend to be mitigated by the taxes that government collects from farmers. As the economy becomes diversified, government assistance to farmers will indirectly increase as government will collect more tax revenues from other sectors and the transfer of agriculture labor from farming to industry or service will imply that more income or sales taxes also will be collected. As the number of farmers decreases per farm size following mechanization of agriculture, the government proclivity to assist farmers will increase.

Data

The data for this research are from the World Bank dataset of indicators of distortions to domestic price of agriculture and non-agriculture commodities drawn from a sample of 40 countries of which 20 are from Sub-Saharan Africa, 12 from Asian developing and 8 from Latin American developing countries. For the purpose of this investigation, we will focus primarily on Sub-Saharan Africa. Those indicators compiled by Anderson and Valenzuela (2011) from 1955 to 2011 contain the nominal rates of assistance to agricultural tradables relative to non-agricultural tradables and the nominal rates of assistance to agricultural importables and agricultural exportables (Bates and Block, 2009). In addition, another indicator "cash-food bias index" shows how producers of cash crops are treated relative to producers of food crops will also be incorporated.

Procedure

Three policy indicators will be considered as variables depicting the level of assistance to farmers namely the relative rate of assistance to agriculture, the trade bias index and the cash food bias index. For this purpose, three regressions will be estimated. In the first regression government level of assistance to farmers will be measured by the relative rate of assistance (RRA) which captures the relative support given to agriculture versus non-agriculture tradables, and it is: (Anderson et al. 2008, Bates and Block, 2009)

$$(1) \quad RRA = \frac{1+NRA_{ag^t}}{1+NRA_{nonag^t}} - 1,$$

where $NRA_{ag^t}$is the nominal rate of assistance to agricultural tradables, and NRA_{nonag^t} is the nominal rate of assistance to non-agricultural tradables.

The second regression seeks to determine whether producers of cash crops compared to producers of food crops benefit the most from government policies. The "cash-food bias" index (CFBI) is: (Anderson et al. 2008, Bates and Block 2009)

$$(2)\quad CFBI = \frac{1+NRAcashcrops}{1+NRAfoodcrops} - 1,$$

where $NRAcashcrops$ refers to the nominal rate of assistance to cash crops and $NRAfoodcrops$ is the nominal rate of assistance to food crops.

The third regression will have the trade bias index (TBI) as a measure of government level of assistance to farmers; it determines the relative assistance of government to exportables versus importables. It is found as follows: (Anderson et al. 2008, Bates and Block 2009)

$$(3)\quad TBI = \frac{1+NRAag_x}{1+NRAag_m} - 1,$$

where $NRAag_x$ is the nominal rate of assistance to agricultural exportables and $NRAag_m$is the nominal rate of assistance to agricultural importable.

Our generic model is:

$$\begin{aligned}(4)\quad y_{it} &= \alpha + \delta_1 Resource\ rich_i + \delta_2 Landlocked_i + \delta_3 Rural\ population\ share_i \\ &+ \delta_4 (Resource\ rich * Rural\ population\ share)_{it} + X_{it}\beta + U_i + \varepsilon_{it}\ ,\end{aligned}$$

where y_{it} is our dependent variable depicting government level of assistance to farmers for country i in year t through the policy indicators defined above, $Resource\ rich$ is a dummy variable for resource rich-countries, $Landlocked$ is a dummy variable for landlocked countries, $Rural\ population\ share$ is the share of a country's population living in rural areas, X stands for the control variables such as real GDP per capita, arable land share in country i in year t, U_i the random disturbance that captures unobserved time invariant country-specific effects, and ε_{it} is the error term associated with country i

in year t. The parameters of our models will be estimated using the fixed effects model following Greene (2010). The fixed effect is specified as:

$$(5)\ y_{it} = X'_{it}\beta + \alpha_i + \varepsilon_{it}\ ,$$

where $\alpha_i = Z'_i\alpha$, embodies all the observable effects and specifies an estimable conditional mean. It implies that Z_i is unobserved, but correlated with X_{it}.

Using these outcomes as the background of their decision making process policy makers in developing countries particularly in Africa may advocate for a transformation of the agricultural sector with an emphasis on improving farmers' wellbeing.

Empirical Results

Table 2 provides the descriptive statistics of the variables of our study. The sample data collected from 1955 to 2011 of 20 sub-Saharan African countries contains 1,020 observations; when accounting for missing data; it is reduced to 505 observations. On average, African countries have adopted policies that could be viewed as detrimental to farming or agriculture in general, with a negative relative rate of assistance to agriculture.

Cash food bias index shows that African countries' governments on average have implemented policies that favor producers of food crops over producers of cash crops. This outcome tends to confirm the logic of collective action (Bates and Block, 2009) which sees urban dwellers influencing government policies in their favor by lowering the cost of food. However, such bias for food crops is good news for African rural population since there still exists excellent growth potential for small producers in the food staples sector (Cereals, roots, and tubers and traditional livestock products). For Africa as a whole, the consumption of these foods accounts for a large part of agricultural output and is projected to double by 2025 with USD 50 billion added to demand (OECD, 2006). In addition, much of this added demand will be translated into market transaction, thus providing growth potential to reach a tremendous number of Africa's rural poor (OECD, 2006)**.**

The trade bias index is negative implying that on average African governments have adopted policies that can be viewed as favoring agricultural importables over agricultural exportables. Out of 505 observations compiled, 25 per cent of them relate to countries that are resource rich while approximately 30 percent of them relate to countries that are landlocked. Out of 505 observations with information about the rural population share on average 72 per cent of the African population live in rural areas. When looking at the gross domestic product per capita on average out of 505 observations, our sample of African countries has a GDP per capita of 1,411 dollars. When looking at the arable land share our data indicate that out of 505 observations on average the proportion of arable land represents 11% in the sample of African countries considered.

Table 3 presents the results of the fixed effects model where three regressions were performed. Model 1 examines the relative rate of assistance to agriculture, model 2 looks at the cash food bias index and model 3 focuses on the trade bias index. The finding of model 1 indicates that being a resource-rich country negatively affects the assistance famers receive from government. The point estimate of resource rich dummy variable is equal to -0.91 and it is statistically significant at 99% confidence level reflecting a tendency for government to favor non-agricultural sectors over agricultural sectors. Governments in landlocked countries enact policies that benefit the agricultural sectors.

Indeed, the landlocked dummy variable enters positively in the RRA estimation with a coefficient equal 0.01 implying government policies that tend to be supportive of the agricultural sector and biased against non-agricultural sector, but it is not statistically significant. The interaction variable between resource-rich country and rural population share, statistically significant at 99% confidence level, shows that rural population has a positive impact on governments implementing policies that favor agriculture in resource-rich countries. In fact, the marginal effect of Rural Population Share which is found as: $-0.004 + 0.016\ Resource\ rich$, shows that if a country is resource-rich, for every percentage increase in the proportion of people living in rural areas, the Relative Rate of Assistance (RRA) increases by: $-0.004 + 0.016 * 1 = 0.012\ \%$. Government tends to implement policies that favor agriculture over non-agricultural sectors in resource rich countries when the size of people living in rural areas increases. The marginal effect of resource-rich which is found as : $-0.910 + 0.016 * rural\ population\ share\ ,$ implies that the effect of resource rich variable in the Relative Rate of Assistance depends on the share of the population living in rural areas; when it is below 57% the marginal effect of resource rich is negative implying a policy biased against agriculture, however the marginal effect becomes positive when the share of the population living in rural area is above 57% implying that governments enacts policies that favor agriculture over non-agricultural sectors if the proportion of people living in rural areas represents the majority of a country's population. A country's gross domestic product (GDP) positively affects government assistance to the agricultural sector, with a coefficient estimate equal to 0.12 and statistically significant at 95% confidence level. For every percentage increase in GDP, the government level of assistance to agriculture increases by 0.12%, reflecting on the ability for the government to provide assistance to agriculture the wealthier a country becomes. The results suggest that the size of a county's arable land negatively affects the ability for government to provide assistance to agriculture, in fact for every percentage increase in the proportion of arable land government assistance to agriculture decreases by 0.004%, but the parameter estimate was not statistically significant.

Model 2 presents the results of cash food bias index which determines whether producers of cash crops compared to producers of food crops benefit the most from government policies. When looking at resource-rich countries, the statistically significant parameter estimate of 0.76 indicates that government policies favor producers of cash crops over producers of food crops.

Although it was hypothesized that geographical location impacts governments' ability to provide assistance to agriculture, with governments in landlocked countries tending to enact policies biased against cash crops in favor of food crops, the parameter estimate was statistically insignificant.

The interaction variable of resource rich country and rural population share enters the model negatively, and it is statistically significant at the 90% confidence level. Marginal effect of Rural Population Share, which is found as follows: $0.003 - 0.008 * resource\ rich$, shows that when a country is resource rich, the marginal effect of Rural Population Share becomes: $0.003 - 0.008 * 1 = -0.005.$ Governments tend to enact policies that favor producers of food crops over producers of cash crops. For every percentage increase in the proportion of people living in rural areas the Cash Food Bias Index (CFBI) decreases by 0.005 if a country is resource rich. When looking at the marginal effect of resource rich country variable: $0.760 - 0.008 *$

$rural\ population\ share$. It shows that the resource rich country variable has a positive effect on Cash Food Bias Index when the Rural Population Share of the Population is less than 95%. Resource-rich countries will enact policies that promote the wellbeing of producers of cash crops over producers of food crops in general.

A country’s gross domestic product also has an influence on governments’ support to agriculture. The parameter estimate of GDP enters positively in the model and it is statistically significant at the 90% confidence level reflecting that for every percentage increase in GDP the cash food bias index increases by 0.099%. Governments tend to implement policies that favor producers of cash crops over producers of food crops as the economy grows. When looking at the proportion of land area arable results indicate that its parameter estimate enters the model positively and it is statistically significant at 99% confidence level, which implies that for every percentage increase in arable land share government level of assistance to producers of cash crops increases by 0.025%. There is a bias against producers of food crops in countries with abundant arable land, which may seem paradoxical. We would assume that countries endowed with abundant arable land would consider developing the agricultural sector by producing agricultural goods in which they have a comparative advantage, and diminish the cost of importing food. Ironically, they still spend a considerable reserve of foreign exchange to import food.

The third model reports the Trade bias index (TBI) which compares government assistance to producers of agricultural exportables relative to producers of agricultural importables. Governments in resource-rich countries tend to enact policies that promote the wellbeing of producers of agricultural exportables over producers of agricultural importable goods. The parameter estimate of the resource rich dummy enters positively in the model and it is statistically significant at the 99% confident level indicating a bias against producers of agricultural importable goods. Governments in landlocked countries have a tendency to enact policies that favor producers of agricultural exportables over producers of agricultural importables. The parameter estimate of the landlocked dummy enters positively in the model and it is statistically significant at 90% confidence level.

When examining the interaction variable between rural population share and resource rich, the coefficient estimate is -0.02 and statistically significant at 99% confidence level. The Marginal effect of rural population share, which is found as follows: $0.002 - 0.02 * \ resource\ rich$, indicates that when a country is resource rich, the effect of the rural population share on the trade bias index (TBI) will be negative, implying that governments in such countries will enact policies that are biased against producers of agricultural exportables as the proportion of people living in rural areas increases. Marginal effect of resource rich, which is found as follows: $1.370 - 0.02 * rural\ pop\ share,$ it is positive when rural population share is below 68.5%. Thus, governments tend to enact policies that favor producers of agricultural exportables over producers of agricultural importables when the share of the population living in rural areas is less than 68.5%.

Although a country's gross domestic product was expected to positively influence the assistance government provides to agriculture, the parameter estimate was not statistically significant. Similarly. Although we expected countries with abundant arable land to favor producers of agricultural exportables over importables, the parameter estimate is not statistically significant.

Summary and Conclusions

This research has focused on factors that affect government assistance to agriculture in sub-Saharan African countries. The policies that African countries implement are dependent on a variety of parameters such as whether it is resource rich, landlocked or has a sizable arable land share. Government policy indicators were measured by the relative rate of assistance to agriculture, the cash food bias index, and the trade bias index. The models were estimated using a fixed effects regression model, and results indicate that governments in resource-rich countries tend to favor: non-agricultural sectors over agriculture, producers of cash crops over producers of food crops, and producers of agricultural exportables over producers of agricultural importables. The parameter estimate of the resource rich dummy variable is statistically significant at the 99% confidence level in all three models.

The proportion of people in rural areas only affects the model when included in the interaction variable with resource-rich countries, and becomes statistically significant at the 99% confidence level for the Relative Rate of Assistance (RRA) model and Trade Bias Index (TBI) model, and statistically significant at the 95% confidence level for the Cash Food Bias (CFBI) index model. When a country is resource rich, governments tend to enact policies that benefit the agricultural sector as the number of people living in rural areas increases. Analogously, producers of cash crops tend to benefit from government policies in resource-rich countries as the number of people living in rural areas increases. Results for the trade bias index show that government policies in resource rich countries tend to be biased against producers of agricultural exportables, thus providing more support to producers of agricultural importables as the proportion of people living in rural areas increases.

We were unable to confirm previous reports that landlocked countries are less biased against agriculture. The relevant variable was statistically insignificant in all the models except for the Trade Bias Index where it was statistically significant at 90% confidence level. In this case, it indicated that landlocked countries tend to enact policies favoring producers of agricultural exportables over producers of agricultural importables.

A country's gross domestic product (GDP) did not have a statistically significant effect on assistance governments provide to agriculture, but higher GDP did tend to favor exportables over importables, and cash crops over food crops.

Surprisingly, we were unable to confirm the effect of arable land share on government's assistance to agriculture. Its parameter estimate turned out to be statistically significant only for the Cash Food Bias index model and it shows that government policies tend to be biased against producers of cash crops as the size of arable land share increases.

Understanding the role of government in agriculture is a complex task. While the price support approach may provide us with a glimpse of what occurs in African countries, more research is needed specifically in the role of the private sector in investment in agriculture, food security, and nutrition in Africa.

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APPENDIX FOR CHAPTER II

Table II-1. Definitions of Dependent and Independent Variables Used for Regression Estimation

Dependent Variable	Definition
RRA	Relative Rate of Assistance
CFBI	Cash Food Bias Index
TBI	Trade Bias Index
Independent Variable	**Definition**
Resource Rich Country	If Yes=1, if No=0
Landlocked Country	If Yes=1, if No=0
Rural Population Share	Share of a country's population living in rural areas
GDP	Real Gross Domestic Product per capita
Arable Land Share	Share of land area that is arable under permanent crops, and under permanent pastures (World Bank)
Country	Sub-Saharan African countries
Year	1955 to 2011

Table II-2. Sample Descriptive Statistics

Variables	Definition	N	Mean	Std. Dev.	Min.	Max.
RRA	Relative Rate of Assistance	505	-0.278	0.317	-0.946	1.295
CFBI	Cash Food Bias Index	505	-0.210	0.397	-0.927	2.216
TBI	Trade Bias Index	505	-0.296	0.402	-0.971	1.419
Resource Rich Country	If Yes=1, if No=0	505	0.250	0.433	0	1.000
Landlocked Country	If Yes=1, if No=0	505	0.297	0.457	0	1.000
Rural Population Share	Share of a country's population living in rural areas	505	72.238	12.214	41.660	95.160
Log GDP	Real Gross Domestic Product per capita	505	7.252	0.633	5.805	9.087
Arable Land Share	Share of land area that is arable under permanent crops, and under permanent pastures (World Bank)	505	10.758	7.973	2.660	33.488
Country	Sub-Saharan African countries 1955 to 2011	505				
Year		505				

Table II-3. Fixed effect models of Government Assistance to Agriculture

	Model 1 (RRA)		Model 2 (CFBI)		Model 3 (TBI)	
Variable	Parameter Estimate	S.E.	Parameter Estimate	S.E.	Parameter Estimate	S.E.
Intercept	-0.550	0.510	-1.420**	0.640	-1.220*	0.780
Resource Rich Country	-0.910***	0.200	0.760***	0.270	1.370***	0.330
Landlocked Country	0.010	0.080	-0.060	0.110	0.230*	0.160
Rural Population Share	-0.004	0.003	0.003	0.004	0.002	0.005
Resource Rich Country*Rural Population Share	0.016***	0.003	-0.008**	0.004	-0.02***	0.004
GDP	0.125**	0.050	0.099*	0.060	0.080	0.070
Arable Land Share	-0.004	0.007	0.025***	0.007	0.008	0.007

Notes: ***=significant at 1% level, **=significant at 5% level, *=significant at 10% level

CHAPTER III

Household Adoption of Water Conservation and Resilience Under Drought: The Case of Oklahoma City

Abstract

Drought response management by utilities in the semi-arid Midwest has been less common outside of Texas than in the Western United States. In response to Oklahoma's unprecedented drought of 2012, Oklahoma City's Water Utilities trust sought to identify the potential for targeting outdoor conservation education and other incentives such as rebates for low flow toilets and soil moisture sensors for irrigation systems. This research uses a unique data set that combines actual household consumption data and county assessor's data of house market value and characteristics with a survey of household conservation adoption of indoor and outdoor water conservation methods. Increased education, age, and income all were found to positively affect indoor and outdoor conservation adoption. Surprisingly neither higher summer consumption during severe drought, nor the perception of prolonged drought increased outdoor conservation adoption, but owning previously conserving Bermuda lawn did increase adoption. However, indoor adoption was higher for homeowners and those who expected prolonged drought. Results suggest that incentives should be targeted at low and average income homeowners and that education regarding the benefits of outdoor conservation should be targeted at all homeowners regarding the higher marginal benefit of seasonal reductions in outdoor watering.

Introduction

Over 91% of the state of Oklahoma was classified as under exceptional drought as of May 20, 2014 (Svoboda, 2014). When lake levels across Oklahoma City's water supply drop below 50%, the city implements mandatory 2 days per week watering restrictions (OKC, 2014). In Oklahoma, summer is the time when demand for water is the highest when high temperatures that prompt residents to demand more water for maintaining turfgrass and landscape plants. Over the long term, Oklahoma City seeks to induce conservation, particularly in outdoor irrigation through education and economic incentives for devices such as smart irrigation soil sensors and timers, such that demand for scarce supplies and developing new water sources is dampened.

This research investigates the determinants of households' adoption of water conservation practices for indoor as well as outdoor uses. Using household level data, the physical and attitudinal factors that affect households' willingness to install water conserving fixtures are examined. In addition, this paper examines households' willingness to change irrigation practices in order to adapt to drought tolerant turf needs. The paper examines variables such as the type of dwelling, household size, gender, age, education, race, income, ethnicity, size of yard, and homeownership status in order to determine how they influence households' adoption of water conserving fixtures and appliances and /or changing irrigation practices to adapt to drought conditions. The model also determines how consumer perceptions of the drought and consumers' current consumption affect adoption of water conservation techniques and technology. This paper uniquely combines survey data with more accurate assessors' data on market value and household characteristics and utility level information on consumption of water during drought.

Literature Review

A great deal of research has been devoted to the issue of water conservation practices either at the farm level or at the urban household level. Berk et al. (1993) concluded that adoption of water efficient devices is strongly correlated with higher education, higher income, having a yard, and being the owner of the house.

We may argue that income at a certain threshold positively influence adoption of water conservation attitudes and appliances in a sense that higher income households would tend to be receptive to adopting water efficient technology as a result of their water use. Unlike households with limited income, high income households are more likely to possess assets such as big homes, large lot space, etc. with high water consumption therefore they could be easily targeted for utility incentive policy that seeks household water efficiency. Renwick and Archibald (1998), in their investigation of household data from two communities in California, found a positive correlation between household income and the number of indoor water-efficient fixtures such as low-flow shower heads and low-flow toilets. However, they stressed that at higher incomes, the probability of using a water-efficient irrigation technology decreased, for example, some wealthier households install automatic irrigation that result in higher water consumption. Worthington and Hoffman (2006) argued that income, through its correlation with education, may reflect water conservation measures taken by the household, through the purchase of water-conserving appliances and planting of drought-tolerant garden vegetation. Mansur and Olmstead (2012), using daily household consumption data that was separated into indoor and outdoor use in 11 urban areas in Canada and the United States, concluded that indoor consumption tends to be affected only by income and family size, while outdoor use is price elastic during the wet season and price inelastic in the dry season. De Oliver (1999) found in San Antonio, TX (1995-

1997) that high income and high education are negatively correlated with conservation. However, Hausman (1979) concluded that the effect of income on adoption of energy-efficient equipment was unclear, he pointed out that richer households were less likely to adopt conservation attitudes since they value savings less than poor households. Looking at income, Martinez-Espineira et al. (2004) argued based on a studied case of Seville (Spain) that:" although water is a normal good, income is not a determining factor in explaining water use, and the parameter associated with the share of supernumerary income allocated to water expenses is not always significant" (Martinez-Espineira et al, 2004).

Owners' age, education, and home ownership tend to increase the adoption of water conservation. Gilg and Barr (2006), and Berk et al. (1993) found that homeowners that are advanced in age were more likely to be informed about water-saving options. Differences by racial composition of farmers in types of property owned and how conservation practices are perceived have been found to affect conservation program adoption at the farm level (Gan et. Al, 2005). Being a home owner positively influences the adoption of water conservation practices, as home owners are more likely to anticipate long term benefits associated with a limited use of water than renters (Millock and Nauges 2010). In addition, being metered for all water uses and charged a volumetric charge on water consumption is likely to reduce consumption compared to flat rate policies, i.e., any volume of use for one price (Millock and Nauges 2010, Renwick and Archibald 1998). Oklahoma City Utilities charges a metered constant rate per volume of $2.65 per 1,000 gallons, a volumetric rate that is relatively low for the state (Adams et al.2009). Literature shows that inclining block rates encourage conservation if higher rates are set at an appropriate level and Oklahoma City may consider this option in the future.

When looking at home age, Mansur and Olmstead (2012) concluded that old and new homes may use less water than “middle aged “homes. They argued that old homes may have smaller connections to water systems and fewer water-using appliances, such as dishwashers and hot tubs, than newer homes. Newer homes may have been constructed with water-conserving toilets and showerheads.

The contribution of this study lies on the fact that it investigates whether households adapt to increasing utility demands following drought given increased irrigation needs and their perceptions of drought and climate change. Understanding risk also requires an understanding of behavior to adapt, mitigate or prevent the potential behavior and impacts of climate change (Botzen and Van den Berg 2012; Longo et al. 2012).

Conceptual Framework and Hypotheses

We hypothesize that adoption of water conservation is affected by a series of factors such as education, income, gender, size of yard, home ownership status, resident’s age, house age, the type of turfgrass, and the number of people in the house (See Figure 1). We expect respondents with greater education, home ownership, older age, and females to be more likely to adopt water conservation practices. We expect older, more educated individuals to be more frugal, aware of possible conservation, and more able to tackle installation of water conservation features. We expect the size of yard and age of the house to negatively affect adoption of water conservation. The intuition is that houses with larger yard size probably use more water for lawn maintenance; thus, as a consequence these households are less likely to adopt water saving behaviors. We expect the effect of household size to be negative as households with younger residents are more concerned with high quality lawns and have less income per resident to enact adoption. Finally, we expect attitudes toward drought to affect adoption of water conservation. Residents who think that the probability of their area suffering a prolonged drought is high will tend to adopt water conservation practices as a result of their perception of drought and climate change. We also expect that greater indoor and outdoor consumption during the 2012 drought will positively affect the likelihood of adoption of water conservation technologies by the end 2013 when they survey was conducted.

<<Figure 1>>

Methodological Model

Adoption models are split into two categories in this paper, indoor and outdoor. Because adoption of both indoor and indoor conservation is rare in Oklahoma, adoption in each of the two categories is bundled as adopting any or multiple technologies as adoption and none as non-adoption. Adoption of a specific water conservation practice was modeled with a binary variable which takes the value of 1 if the practice is adopted and 0 if it is not (Greene, 2000).

Suppose that Y_a and Y_{na} respectively represent individual's utility of two choices, adoption and non-adoption of water conservation practice, which might be denoted as U^a andU^b. The observed choice between the two reveals which one provides the greater utility, but not the unobservable utilities. Hence, the observed i indicator equals 1 if $U^a > U^b$ and 0 if $U^a \leq U^b$, i.e., non-adoption. Linearized, this is as follows (Greene, 2000):

$$U^a = \beta_a X + \varepsilon_a \; and \; U^b = \beta_b X + \varepsilon_b \tag{1}$$

Then, if we denote by $Y = 1$ the individual's adoption of water conservation practice a, we have (Greene, 2000):

$$Prob[Y = 1 \,|\, \mathrm{X}] = \mathrm{Prob}[U^a > U^b] \tag{2}$$

$$= Prob[\beta_a X + \varepsilon_a - \beta_b X - \varepsilon_b > 0 \,|\, \mathrm{X}] \tag{3}$$

$$= Prob[(\beta_a - \beta_b)X + \varepsilon_a - \varepsilon_b > 0 \,|\, \mathrm{X}] \tag{4}$$

$$= Prob[(\beta X + \varepsilon > 0 \mid \mathrm{X}], \text{where } \beta = \beta_a - \beta_b, and\ \varepsilon = \varepsilon_a - \varepsilon_b \quad (5)$$

$$= F(X\beta), where\ F(X\beta)\ represents\ a\ cumulative\ distribution\ function \quad (6)$$

Logit Model

The logit model was used to predict the likelihood of adoption and the errors are assumed to follow a logistic cumulative distribution (Feder and Umali 1993). The logit model is defined as follows:

$$P(Y = 1) = \frac{\exp(X\beta)}{1 + \exp(X\beta)}, \quad (7)$$

Where Y equals 1 if one of the conservation methods is adopted and 0 otherwise and X is the row of independent variables and β is the corresponding parameter vector of coefficients that affect the likelihood of adoption.

Four separate estimations of the probability of adoption, indoor and outdoor technology adoption were conducted. Models I and II predicted the likelihood of indoor adoption, where the second model uses the additional variables for actual indoor consumption for 2012 and the belief of a persistent drought. Models III and IV predicted the likelihood of outdoor adoption, where the fourth model used actual outdoor consumption for 2012 and one expectation of a persistent drought. For outdoor water conservation, adoption was considered to have occurred if the household had adopted any of one of the following practices: the use of catch cups to audit irrigation, i.e., measuring how much water has been used, measurement of how uniformly the yard is watered, the purchase of drought-tolerant lawn and/or garden plants, and/or the use of rain barrels and/or a cistern to collect water for reuse. For the indoor water conservation dependent variable, the household was considered an adopter if it had installed any of the following technologies: low-flow or water sense labeled faucets or showerheads, ultra–low flow or water-sense toilet, and/or water-conserving or energy star certified dishwasher. Research shows that domestic water-saving devices (for example the adoption of low-flow toilets, showerheads, and faucets) and certain garden irrigation technologies reduce water consumption significantly (Renwick and Archibald, 1998; Chesnutt et al., 1992).

Data and Results

This study used household level water indoor and outdoor conservation technique adoption data collected from 797 households in Oklahoma City, Oklahoma. From December 2013 through February 2014, the "Oklahoma Household Water Conservation Preference Telephone Survey" was administered to Oklahoma City Water Utilities' customers in order to gather information on water conservation technology adoption and demographic statistics. From contact information provided by Oklahoma City Billing records, 3,333 valid numbers were contacted five times, and of these, 2,308 declined to participate. In the end, a total of 803 surveys were completed with a final number of 797 useable surveys. The response rate was 24.1 % based on contacted households, but with attitude and consumption variables, models 3 and 4 include 783 individuals. Completed surveys were then matched by address with consumption data from actual customer records for January 2012 – March 2014 (Xie, 2014). Finally, these households were also mapped in a geographic information system (Arc 9) with Oklahoma County Assessor's Data for 2011 to obtain house market value, accurate house age, square footage and parcel square footage (Bryan, 2014). Table 1 provides definitions and units of measurement for the dependent and independent variables.

<<TABLE 1>>

Table 2 provides summary statistics of the variables for the sample. The sample is disproportionately educated compared to most Oklahomans. Seven percent of households that responded to the survey have some high school education, while 17% have a high school diploma. 29% of households have some college education, while 29% have a college degree (BA /BS). In addition, 18% of households reported having an advanced degree. The 2012 US Census reports 85% of Oklahoma City's residents had a high school diploma and 28% had earned a Bachelor's degree (Census, 2014). The average age was 54 years. Looking at house age, on average respondents live in a house that is 43 years old with a standard deviation of 16.89 years. The average number of residents in a household was 3. The sample is disproportionately female at 60% and made up of homeowners at 86%. Roughly 54% of sampled households earn under $40,000, 25% have an income between $40,001-75,000 annually, and 21% of households earn over $75,001 dollars. For reference, the 2012 U.S. Census reports median household income as $45,704/year for the period 2008-2012 and 17.6% of residents live below the poverty level of Oklahoma City (U.S. Census Bureau, 2014). Out of 783 people in the restricted sample, 70% are white, 12% are African-American, 3 % are Asian, and 15% are of other races (Native Americans, Multi-Racial, others). The sample is fairly representative of race as reported in the 2010 U.S. Census 62.70% of Oklahoma City residents were white, 15.10% were African American, and 6.3% were of other races (American Indian &Alaska Native, two or more races) (U.S. Census Bureau, 2014). Looking at the sample, 8.56% of respondents are Hispanic. However, 17.20% of Oklahoma City residents identified themselves as Hispanic in the 2010 (U.S. Census Bureau, 2014). The survey was administered in Spanish upon request.

<<Table 2>>

Figure 2 illustrates household water consumption (thousands of gallons) for the 2012-2014 period. Household water consumption in winter was calculated by averaging individual monthly consumption for January, February and March. Summer consumption was calculated by averaging monthly consumption of June, July, and August. As shown in Figure 2, on average, winter consumption for 2012 was 5.14 thousand gallons per month with a maximum of 59.67 thousand gallons per month. For the summer of the same year, average water consumption was 10.1 thousand gallons per month with a maximum of 80 thousand gallons per month. Therefore, the summer incremental consumption was on average 4,960 gallons per household in summer for outdoor irrigation and activities, almost 50% of average summer consumption. Water conservation education may have more impact on influencing outdoor adoption to reduce summer water consumption, but as the results show, consumers by far have embraced indoor technologies over outdoor conservation. Winter consumption for year 2013 was 5.24 thousand gallons (per month) on average with a maximum of 51.67 thousand gallons per month, and summer consumption was 7.69 thousand gallons per month with a maximum of 52.66 thousand gallons per month. Since the drought was at its height in summer 2012, the higher average monthly use in summer is to be expected to offset lack of precipitation and increased evapotranspiration.

<<Figure 2>>

In this research, a household's likelihood of adopting indoor and outdoor water conservation practices was studied. The outdoor water conservation variable is considered an adoption if a household has used of catch cups to measure how much water has been used and how uniformly the yard is watered, has purchased drought-tolerant lawn and/or garden plants, and finally has used rain barrels and/or cistern to collect water for reuse. The indoor water conservation variable is considered as an adoption if household has installed low-flow or water sense labeled faucets or showerheads, ultra –low flow or water-sense toilet, and/or purchased water-conserving or energy star certified dishwasher. Table 3 shows estimated coefficients for a logistic models using SAS 9.3. Four models were estimated; model 1 and model 3 are the reduced or basic models and models 2 and 4 are the expanded models for outdoor and indoor conservation respectively that include variables for the perception of drought and actual consumption. Table 4 shows the Odds Ratio Estimates for Models 1-4 with the levels at which they are significant. Models 1 and 2 predicted outdoor adoption in 79.8% and 79.9% of the cases, whereas the indoor adoption models predicted 63.3% and 64.9% respectively (Table 3).

Outdoor Adoption (Models I -2)

For outdoor adoption of water conservation as shown in models 1, and 2, a household that has adopted indoor conservation methods is likely to adopt an outdoor practice (significant at the 99% confidence level in both models). In fact, a respondent that adopted an indoor practice is 5.31 and 5.41 times more likely to adopt an outdoor conservation practice than one who has not in models 1 and 2 respectively. Education at all levels above high school is significant in models 1 and 2 at 90% and 99% confidence levels respectively when compared to those with less than high school, the dropped variable (Table 3). Compared to someone without a high school degree, a respondent with some college, college graduate or advanced degree is 2.61, 3.6 and 6.69 times more likely to adopt an outdoor conservation technique respectively. For each year of increase in respondent’s age, there is a 1.01 increase in the likelihood of adoption of outdoor conservation. This result suggests, as previously shown in the literature, older individuals have more familiarity with the need for outdoor conservation over time and perhaps a preference for saving water (Gilg and Barr, 2006; Berk et al., 1993). Compared to the reference variable, Caucasians, African Americans respondents were less likely in both model 1 and 2 to adopt outdoor water conservation at the 90% significance level. The odds for adopting outdoor water conservation practices is 54% less for African Americans compared to Caucasians. None of the other race or ethnicity variables were significant. Yard size and house size were not significant, nor was market value. Those who identify their lawns as predominantly Bermuda grass were more likely to adopt water conservation behaviors. Given that Bermuda is a water efficient plant, a household that has chosen Bermudagrass already has chosen the most heat and drought tolerant grass available for the region rather than other turf types such as fescue which requires more water, is more shade tolerant, and less coarse in texture (Moss et. al., 2013). In fact, those residents with Bermuda grass on their lawn were 1.9 times more likely to adopt outdoor water conserving behavior than residents that did not have Bermuda grass. Surprisingly neither gender, nor homeownership, were significant, but the signs are as expected, i.e., we expect vested residents to be more likely to adopt outdoor conservation. We suspect that low water prices and temporary or seasonally fluctuating pressure problems have not pushed homeowners to invest in outdoor conservation such as soil moisture sensors for irrigation which can run $300-500 per unit without including installation. Income levels above $75,000 did significantly and positively affect adoption at the 99% confidence level. The odds for adopting outdoor water conserving behavior for residents with incomes above $75,000 compared to those with incomes below $40,000 is 1.86 times more in the expanded model for outdoor adoption in model 2, neither the belief in the likelihood of drought, nor summer consumption during summer of 2012 proved significant (Table 3). Summer of 2012 in Oklahoma will be remembered as one of the driest periods that the state ever experienced, with an average monthly consumption of 10,000 gallons per household in the summer months, thus we expected both perception of drought continuation and the increased bills due to high consumption in summer 2012 to increase adoption on average (US Drought Monitor, 2012)

Indoor Adoption (Models 3-4)

Similar results to the outdoor adoption model are found for models 3 and 4 for indoor adoption as shown in Table 3. In both the basic (model 3) and enhanced models (model 4), for all levels of education above high school, there was a significant likelihood of adoption when compared to those with less than a high school education, holding all else constant. For the basic model, homeowners were more likely to adopt indoor conservation fixtures at the 99% confidence level. In fact, the odds of adopting indoor conservation fixtures was about 1.65 times higher for homeowners than for residents that were not owners; however, this variable was not significant in model 4. House age in model 3 was more likely to negatively and significantly affect adoption of fixtures which seems inconsistent with the idea of replacing old fixtures with new as a house ages, but perhaps owners of older homes do not invest in more expensive features. Land prices and commuting times in Oklahoma City remain low, making it less likely that renovations on homes are high end regentrification with efficient appliances. Households with income levels above $75,001 per year are significantly more likely to adopt indoor conservation fixtures compared to households earning less than 40,000 at the 99% confidence level, but this was true only in model 4, with an odds ratio of 1.32 implying that the odds for adopting indoor conservation fixtures was 32% higher for residents with income level above $75,001 than for residents making less than $40,000.

Surprisingly, market value, house square footage, the number of household members, and winter consumption were not significant in the indoor models 3-4. None of the ethnicity or race variables were significant. The belief that there would be a prolonged drought does significantly affect the likelihood of indoor adoption in the enhanced model 4 at the 99% confidence level. In fact, with an odds ratio of 1.54, residents that believed that there would be a prolonged drought were 1.54 times more likely to adopt indoor water conservation fixtures than those who did not agree.

<<TABLE 3>>

<<TABLE 4>>

Likelihood ratio tests were performed to compare model 1 to 2, and model 3 to 4 to determine whether any of the basic/reduced models fit significantly better than the full model. The likelihood ratio test between model 1 and model 2 tests the null hypothesis restriction that the dummy variable “likelihood area’s prolonged drought increasing” and “summer average water consumption 2012” are equal to zero. For outdoor adoption of water conservation, the likelihood ratio test statistic is equal to 974.51-971.53 = 2.98. With a $\chi^2(0.05; 24-22) = 5.99 > 2.98$, the two attitude questions in the outdoor adoption of water conservation should not be added to the model, therefore the reduced model (model 1) is the appropriate one. The likelihood ratio test between model 3 and model 4 was almost the same as the initial one, except the hypothesis restriction included winter average water consumption 2012 instead of summer. For indoor adoption of water conservation, the likelihood ratio test statistic is equal to 994.32-988.26=6.06. The Chi-Square statistic is $\chi^2(0.05; 21-19) = 5.99$. Since 6.06 > 5.99, the threshold for the test, the two attitudinal questions regarding the resident’s area suffering a prolonged drought and spring average water consumption should be added to the regression model, therefore model 4 (the full model) should be kept.

Conclusion

This article has focused on the determinants of household adoption of water conservation technologies and practices using demographic, house characteristics, attitudes and water consumption data gathered from Oklahoma City water utilities customers. Based on the outcomes from the logit models, we may assert that education and higher income levels are contributing factors in explaining both indoor and outdoor adoption of water conserving behavior. We have found a threshold at which the variable income leads to the adoption of water conserving behavior. Households making more than $75,000 a year were more likely to adopt indoor, as well as outdoor water conservation practices, compared to households making less than $40,000. Therefore, in order to expand adoption, policymakers might consider targeting toilet or soil moisture rebates to average and lower income households given they are less likely to do so independently. We did not find enough evidence to support the claim that the size of the yard affects outdoor adoption of water conservation, but households that have Bermuda grass as the type of turfgrass in their lawn are more likely to adopt water conserving behavior compared to households that have other types of turfgrass in their lawn.

Many of the included assessor characteristics such as house age, market value, and house size were insignificant in both the indoor and the outdoor adoption models, except in model 3 for indoor conservation where residents in older houses were less likely to adopt indoor fixtures. Gender, race, and ethnicity proved to be insignificant except for African American households, which were less likely to adopt outdoor conservation, and older residents which were more likely to adopt outdoor but not indoor conservation.

Attitudes and consumption only mattered for indoor adoption of fixtures, but those who adopted indoor water conserving fixtures were significantly more likely to adopt outdoor conservation measures. We could not support the claim that household's perception of increasing drought affects adoption of water conservation except in the enhanced model for indoor conservation (model 4). When adding household water consumption and the household's perception of increasing drought, the likelihood ratio test revealed that they only made a difference for indoor adoption of water conservation.

Consumption variables did not have the expected effect in 2012, perhaps because rates continued to be low per 1000 gallons consumed. Our research on training residents about outdoor conservation suggests that our results for outdoor adoption make intuitive sense. The act of auditing the yard and researching plants requires effort on the part of the homeowner, suggesting that education and increasing access to information about consumption will help Oklahoma City's efforts for managing water demand. In fact, as Sutherland (1991) noted: "Policies that encourage the dissemination of information, such as appliance labelling, may promote energy efficiency and overall economic efficiency". Indoor conservation has benefited from labelling systems such as water sense ™ labeling which is visible at the time of purchase and in advertising (EPA, 2014).

However, outdoor irrigation systems with smart technology are largely installed by landscaping companies with little input from the consumer. If landscaping companies do not recommend a soil moisture or rain sensor to stop irrigation when it is not needed, install a difficult to program irrigation controller, and fail to measure the amount of water being applied to the lawn and adjust it to the lawn's needs, homeowners may actually use more water than ever before. In this survey, only 20% of respondents agreed or strongly agreed that they were "confident in their ability to adopt ways to conserve irrigation water." As a result, Oklahoma City's Water Utility Trust, which funded this research has approved a three-year program to provide homeowners with training in conducting lawn sprinkler audits and factsheets on drought tolerant turf and plants. This Oklahoma State University project has targeted homeowner associations and lawn companies with training in audits to reduce wasteful watering. Unfortunately, we know the most inefficient behaviors, such as watering mid-day and in high winds have decreased, but individual measurement of watering efficiency has not gained widespread acceptance.

Further research is still needed to help understand other factors that contribute to household's adoption of water conservation behavior, but more than just Oklahoma City residents have a vested interest. Having reached critically low reservoir levels in 2013 and resorting to the politically unpopular decision of exercising rights to water in an upstream, recreational reservoir in Canton, OK, which remains critically low at 24.6% full (USACE, 2015). Oklahoma City raised rates. In July 2014, the city of Oklahoma City implemented an inclining block rate structure, but the levels of $2.65/1000 gallons for the first tier remain low up from the previous volumetric pricing rate $2.55/1000 during our survey period. The second tier only starts at 10,000 gallons, which we saw was the average consumption only in the hottest, drought year of 2012 (Oklahoma City, 2015). These rates are lower than other similarly sized communities such as Tulsa ($3.40/1000 gallons, volumetric) or smaller communities such as Stillwater, OK ($5.65/1000, volumetric) (Wertz, 2013). Conservation adoption may remain slow in the absence of significant rebates and may boil down to raising the relatively low cost of water. Without significant conservation of current supplies, Oklahoma City will continue to exercising their rights to expensive alternative supplies from other communities such as Lake Sardis or Canton, Lake, both very politically charged issues in Oklahoma.

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Figure III-1. Hypothesized Influence of Independent Variables on Indoor and Outdoor Adoption of Conservation Measures

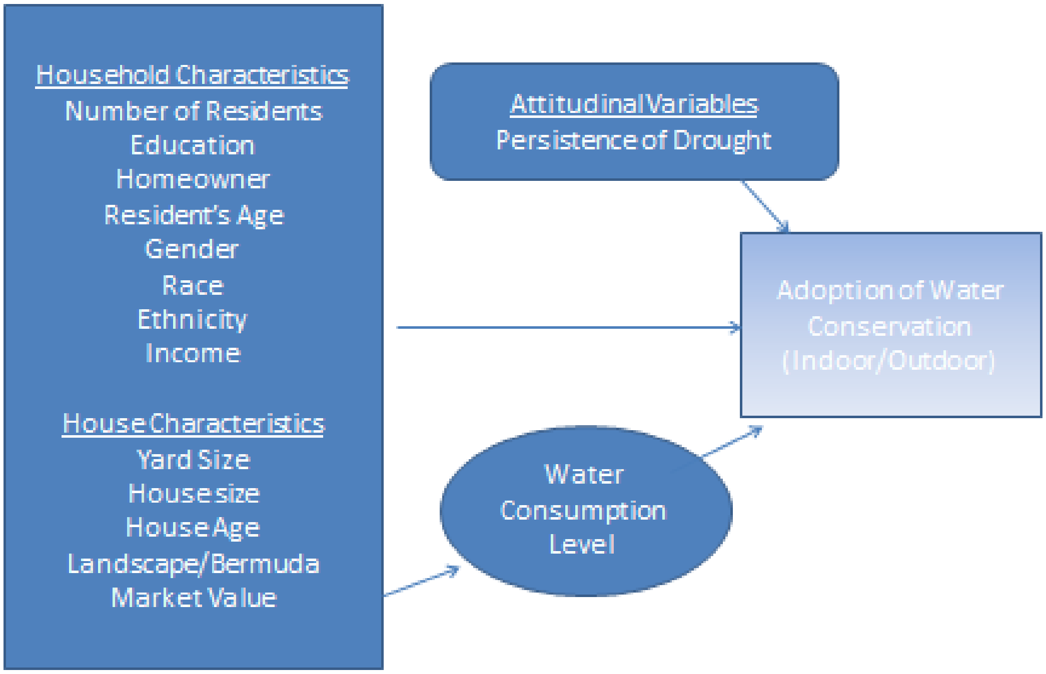


Table III-1. Definitions of Dependent and Independent Variables Used for Logit Estimation

Dependent Variable	Definition
Indoor adoption	Low-flow or water sense labeled faucets or showerheads. Ultra –low flow or water-sense toilet. Water-conserving or energy star certified dishwasher.
Outdoor adoption	The use of catch cups to measure how much water has been used and how uniformly the yard is watered. The purchase of drought-tolerant lawn and/or garden plants. The use of rain barrels and/or cistern to collect water for reuse.

Independent Variables	Definition
Likelihood prolonged drought increasing	If yes=1, if no=0
Winter average water consumption 2012	Jan, Feb, March cons., 1000s of gallons
Summer average water consumption 2012	June, July, Aug. cons., 1000s of gallons
Number of people in the house	Household size
High school graduate	if yes=1, if no=0
Some college	if yes=1, if no=0
College graduate	if yes=1, if no=0
Advanced degree	if yes=1, if no=0, JD, MS, PhD.
Homeowner	if yes=1, if no=0
Age	Residents Age in Years
Resident's age	
Age	Resident's Age
Gender	if male=1, otherwise=0
Black	if yes=1, if no=0
Asian	if yes=1, if no=0
Other Races	if yes=1, if no=0, Native American, Multi-Racial
Hispanic	if yes=1, if no=0
Yard size	in square feet
Yard size squared	in square feet
House size	in square feet
House age	in years
House age squared	in years
Bermuda	if yes=1, otherwise=0, Type of Turf
Market value	Dollars, 2011 US, Assessed
Income <=$40,000	Household income level (if yes =1, if no=0) (Used dropped reference variable)

Income $40,001-$75,000	Household income level (if yes =1, if no=0)
Income above $75,000	Household income level (if yes =1, if no=0)

Table III-2. Sample Descriptive Statistics (n=783, sample for models II and IV)

Variables	Definition	Mean	Std. Dev.	Min.	Max.
Outdoor adoption	if adopted =1, otherwise=0	31.16%	46.34%	0	1
Indoor adoption	if adopted =1, otherwise=0	32.57%	46.89%	0	1
Likelihood area's prolonged drought increasing	If yes=1, if no=0	39.20%	48.85%	0	1
Winter avg water consumption 2012	Jan, Feb, March cons.(1000s of gallons)	5.14	4.10	0.33	59.67
Summer avg water consumption 2012	June, July, Aug. cons.(1000s of gallons)	10.10	9.76	1.33	80
Winter avg water consumption 2013	Jan, Feb,March cons.(1000s of gallons)	5.24	4.07	0.33	51.67
Summer avg water consumption 2013	June, July, Aug. cons.(1000s of gallons)	7.69	6.35	0.33	52.66
Number of people in the house	Household size	3	2	1	17
some high school	if yes=1, if no=0	6.64%	24.92%	0	1
High school graduate	if yes=1, if no=0	16.86%	37.46%	0	1
Some college (or trade/vocational school)	if yes=1, if no=0	28.74%	45.28%	0	1
College graduate (B.A., B.S)	if yes=1, if no=0	28.61%	45.22%	0	1
Advanced degree (MD.,J.D.,M.A.,M.S., or PhD)	if yes=1, if no=0	17.75%	38.24%	0	1
Don't know level of education	if yes=1, if no=0	1.40%	11.78%	0	1
Homeowner	if yes=1, if no=0	86.33%	34.37%	0	1

Resident's age	in years	54.00	22.00	27	97
Gender	if male=1, otherwise=0	40.10%	49.04%	0	1
White	if yes=1, if no=0	69.99%		0	1
Black	if yes=1, if no=0	11.62%	32.07%	0	1
Asian	if yes=1, if no=0	3.43%	11.78%	0	1
Other races (Native American, Multi-racial, others)	if yes=1, if no=0	14.17%	34.90%	0	1
Hispanic	if yes=1, if no=0	8.56%	27.99%	0	1
Yard size	in square feet	8167.86	23935.94	417	469700
Yard size^2	in square feet	638911262	10012892104	173889	22.06E+10
House size	in square feet	1462.78	2118.89	696	56525
House age	in years	43.36	16.89	6	108
House age^2	in years	2164.64	1684.35	36	11664
Bermuda	if yes=1, otherwise=0	54.53%	49.82%	0	1
Market value	in dollars	97898.69	94420.29	17292	1248941
Income below $40,000		53.63%	49.90%	0	1
Income level $40,001-$75,000		25.29%	43.49%	0	1
Income level above $75,001		21.08%	40.81%	0	1

Table III-3. Indoor and Outdoor Adoption Logit Estimations
(Adoption of Any Indoor or Any Outdoor Method as Dependent Variable) (Models I-IV)

	Model 1 (Outdoor)		Model 2 (Outdoor)		Model 3 (Indoor)		Model 4 (Indoor)	
Variable	**Coefficient**	**SE**	**Coefficient**	**SE**	**Coefficient**	**SE**	**Coefficient**	**SE**
Intercept	-3.31***	0.82	-3.42***	0.83	-1.23*	0.68	-1.41**	0.69
Indoor adoption	1.67***	0.18	1.69***	0.19				
Likelihood area's prolonged drought increasing (if yes=1, if no=0)			0.15	0.18			0.43***	0.16
Winter avg water consumption 2012 (in 1000s of Gallons)							-0.003	0.02
Summer avg water consumption 2012 (in 1000s of Gallons)			0.01	0.01				
Enrollment in Price smoothing averaging (if yes=1, if no=0)	-0.004	0.19	0.0003	0.19	-0.06	0.17	-0.05	0.17
Number of people in the house (Household size)	-0.02	0.06	-0.03	0.07	-0.01	0.004	-0.02	0.05
High school graduate (if yes=1, if no=0)	0.88	0.54	0.86	0.54	0.39	0.43	0.36	0.43
Some college (if yes=1, if no=0)	0.96*	0.52	0.91*	0.52	0.97**	0.41	0.94**	0.41
College graduate (if yes=1, if no=0)	1.28**	0.53	1.26**	0.53	0.84**	0.42	0.79*	0.42
Advanced degree (if yes=1, if no=0)	1.9***	0.54	1.84***	0.55	0.88**	0.44	0.77*	0.44
Homeowner (if yes=1, if no=0)	0.04	0.35	0.05	0.35	0.98***	0.3	0.97	0.31
Resident's age (in years)	0.01**	0.005	0.01**	0.004	-0.005	0.004	-0.005	0.004
gender (if male=1, otherwise=0)	0.26	0.18	0.24	0.19	0.1	0.16	0.13	0.17

Table III-3. Indoor and Outdoor Adoption Logit Estimations (Models I-IV) Continued

	Model 1 (Outdoor)		Model 2 (Outdoor)		Model 3 (Indoor)		Model 4 (Indoor)	
Variable	Coefficient	SE	Coefficient	SE	Coefficient	SE	Coefficient	SE
Black (if yes=1, if no=0)	-0.77**	0.33	-0.74**	0.33	-0.09	0.26	-0.07	0.26
Asian (if yes=1, if no=0)	-0.16	0.77	-0.1	0.78	-1.12	0.82	-1.01	0.83
Other races (Native American, Multi-racial, other)	-0.48	0.32	-0.45	0.32	0.04	0.27	0.06	0.27
Hispanic (if yes=1, if no=0)	0.52	0.45	0.50	0.45	-0.34	0.38	-0.36	0.38
Yard size (in square feet)	3.99E-12	0.000016	1.08E-06	0.000016				
Yard size squared (in square feet)	-2.60E-11	4.95E-11	-162E-13	5.19E-11				
House size (in square feet)					-0.00005	0.0001	-0.00005	0.0001
House age (in years)	-0.008	0.02	-0.01	0.02	-0.03*	0.02	-0.03	0.02
House age squared (in years)	-0.00001	0.0002	8.46E-06	0.0002	0.0002	0.0001	0.0002	0.0001
Bermuda (if yes=1, if no=0)	0.64***	0.19	0.62***	0.19				
Market value (in dollars)	1.79E-07	1.16E-06	-3.01E-07	1.24E-06	-3.59E-07	1.37E-06	-2.74E-07	1.40E-06
Income level $40,001-$75,000 (in dollars)	-0.15	0.23	-0.14	0.23	0.23	0.2	0.25	0.20
Income level above $75,001 (in dollars)	0.62***	0.24	0.63***	0.24	0.22	0.22	0.28***	0.22
N	787		783		787		783	
LR Chi2	197.53		200.09		48.55		56.75	
Prob Chi2	<0.0001		<0.0001		0.0001		<0.0001	
Log Likelihood	-388.49		-385.72		-472.88		-465.45	
Pseudo R2	20%		21%		5%		6%	
% Correctly predicted	79.8%		79.9%		63.3%		64.9%	

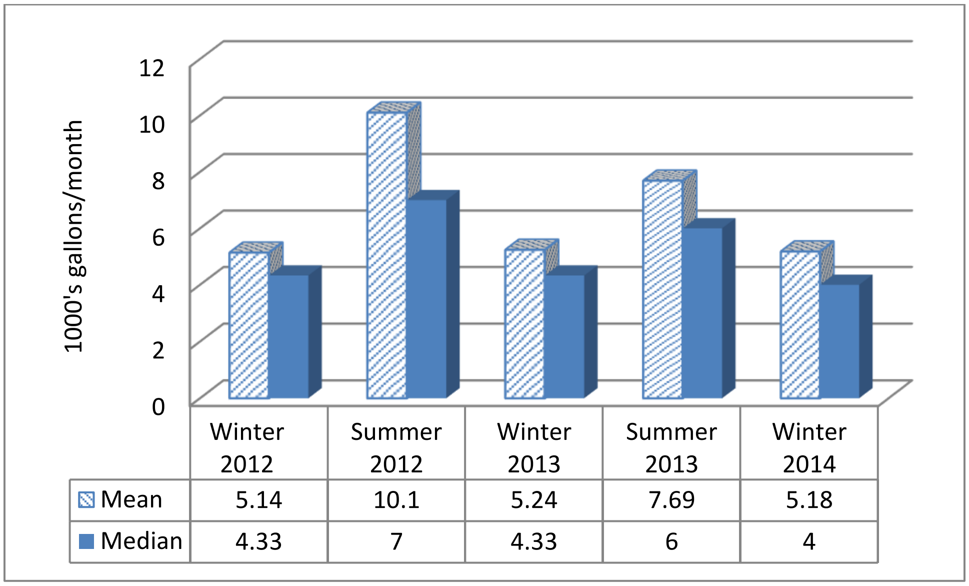
Table III-4. Odds Ratio Estimates for Indoor and Outdoor Conservation Method Adoption (Models I-IV)

	Model 1 (Outdoor)	**Model 2 (Outdoor)**	**Model 3 (Indoor)**	**Model 4 (Indoor)**
Variable	**Point Estimate**	**Point Estimate**	**Point Estimate**	**Point Estimate**
Indoor adoption	5.31***	5.41***		
Likelihood area's prolonged drought increasing (if yes=1, if no=0)		1.16		1.54***
Winter avg water consumption 2012 (in 1000s of Gallons)				1
Summer avg water consumption 2012 ((in 1000s of Gallons)		1.01		
Enrollment in Price smoothing averaging (if yes=1, if no=0)	1	1	0.94	0.95
Number of people in the house ((Household size)	0.98	0.97	0.99	0.98
High school graduate ((if yes=1, if no=0))	2.41	2.36	1.48	1.43
Some college (if yes=1, if no=0)	2.61*	2.48*	2.64**	2.6**
College graduate (if yes=1, if no=0)	3.6**	3.53**	2.32**	2.20*
Advanced degree (if yes=1, if no=0)	6.69***	6.3***	2.41**	2.16*
Homeowner (if yes=1, if no=0)	1.04	1.05	2.66***	2.64
Resident's age (in years)	1.01**	1.01**	1	1
Gender (if male=1, otherwise=0)	1.3	1.27	1.11	1.14

Table III-4. Odds Ratio Estimates for Indoor and Outdoor Conservation Method Adoption (Models I-IV) Continued

	Model 1 (Outdoor)	**Model 2 (Outdoor)**	**Model 3 (Indoor)**	**Model 4 (Indoor)**
Variable	Point Estimate	Point Estimate	Point Estimate	Point Estimate
Black (if yes=1, if no=0)	0.46**	0.48**	0.91	0.93
Asian (if yes=1, if no=0)	0.85	0.90	0.33	0.36
Other races (Native American, Multi-racial, other)	0.62	0.64	1.04	1.06
Hispanic (if yes=1, if no=0)	1.68	1.65	0.71	0.7
Yard size (in square feet)	1	1		
Yard size squared (in square feet)	1	1		
House size (in square feet)			1	1
House age (in years)	0.99	0.99	1*	0.97
House age squared (Years)	1	1	1	1
Bermuda (if yes=1, if no=0)	1.9***	1.86***		
Market value (in dollars)	1	1	1	1
Income level $40,001-$75,000 (in dollars)	0.86	0.87	1.26	1.28
Income level above $75,001 (in dollars)	1.86***	1.88***	1.25	1.32***

Figure III-2: Average and Median Oklahoma City Monthly Residential Water Consumption (1000s of Gallons. N=783)



	Winter 2012	Summer 2012	Winter 2013	Summer 2013	Winter 2014
▨ Mean	5.14	10.1	5.24	7.69	5.18
■ Median	4.33	7	4.33	6	4

Summer Average taken over June, July, and August
Winter Average taken over January, February, and March

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