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Cost-Benefit Analysis and Potential Spillover Effects of Farmer Field Schools in Sub-Saharan Africa: The Case of Cocoa

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Abstract

This thesis consists of two studies analyzing the first phase of the Cocoa Livelihood Program (CLP-I), a current World Cocoa Foundation (WCF) development project, sponsored by the Bill and Melinda Gates Foundation and aimed at improving the livelihood of small scale cocoa producers in Sub-Saharan Africa. The first study uses a difference-in-differences econometric model to estimate yield enhancements attributable to farmer field schools which CLP implements. The results show a 32%, 34%, 50% and 62% increase in cocoa yield for Ghana, Côte d'Ivoire, Nigeria and Cameroon, respectively. These yield enhancements have the potential to increase income by 26%, 29%, 48%, and 87% for cocoa farmers in Ghana, Côte d'Ivoire, Nigeria and Cameroon, respectively. The benefit-cost ratios of the program are estimated to range from US $18- US $62. Building on the results from the econometric analysis, the second study develops a Farm Household Model to analyze the direct cocoa market and indirect spillover effects of CLP and demand expansion on equilibrium price and quantities in the Ghanaian food and cocoa markets, and welfare. The results show that net welfare gains are higher for CLP households relative to non-CLP households. The spillover effects in the maize, cassava, and yam markets are minimal while the rice market experiences a modest increase in its price. The net welfare for Ghana and the world are both positive. Sensitivity analysis shows that cocoa price declines as the CLP participation rate increases and rises as world cocoa demand expands. Also, at a CLP participation rate greater than 59%, net gains from the program in Ghana become negative due to a declining cocoa price as supply increases. Based on these results, CLP could be expanded from its current rate of 6.25% of cocoa farmers to 59%. However without demand expansion, expanding CLP participation beyond 59%, will lead to welfare losses in Ghana. Hence, marketing and cocoa demand expansion are equally as

important as production expansion to increase rural farm household income. Hence, marketing and cocoa demand expansion are equally as important as production expansion to increase rural farm household income. Given the expected increase in world cocoa demand, this is a crucial time to promote Sub-Sahara African cocoa and further establish supply links in this burgeoning market.

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First and foremost, I thank God for seeing me through this programme successfully. I owe a debt of gratitude to my supervisors, Dr. Lawton L. Nalley, Dr. Jennie S. Popp, Dr. Bruce L. Dixon, and Dr. Jeff Luckstead for providing me with the necessary guidance, constructive criticisms and their time, without which this work would not have been possible. I also express my heartfelt gratitude to all lecturers and staff of the Department of Agricultural Economics and Agribusiness. Words cannot express my appreciation to the World Cocoa Foundation for the funds they gave in order to verify the data used in this thesis, and the hospitality given by their Accra field office staff. May God richly bless you.

Dedication

This thesis is dedicated to the Almighty God, the one who has given me strength and grace to go through my two years of graduate education. It is also dedicated to my beloved mother Comfort Lomotey and father Alfred Isaac Tsiboe-Darko, who together played major roles in nursing and educating me.

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Chapter I: Introduction

Cocoa is the highest export revenue earning agricultural commodity exported from Sub-Saharan Africa, averaging about US $6.5 billion in 2011-2012 (UN Statistics Division, 2015). Approximately 70% of the world's cocoa exports originate from Sub-Saharan Africa; in 2010-2011 Côte d'Ivoire accounted for 37% of world cocoa exports, followed by Ghana (24%), Nigeria (7%), and Cameroon (6%) (ICCO, 2012). Cocoa exports account for 15% of GDP in Côte d'Ivoire, 3.2% in Ghana, 3% in Cameroon, and 1% in Nigeria. Approximately 90% of cocoa is produced by about two million small-scale household farms on two-to-four hectare plots with little formal agricultural training. Given the historically low levels of cocoa production relative to other cocoa production regions, and the lack of extension services available, cocoa farmers have difficulty addressing issues such as yield loss—about 30% annually—due to pests and diseases, inadequate access to inputs, antiquated farming techniques, limited availability of improved varieties, and limited organizational support (ICI, 2011). Together these factors have ultimately led to lower cocoa yields relative to those found in Asia and North America, and lower or even negative returns on cocoa production. Solutions to these challenges are often offered in high-income countries by agricultural extension agencies. In many Sub-Saharan countries, agricultural extension services were eliminated during the IMF/World Bank structural adjustment periods.

To fill the cocoa extension gap, the Cocoa Livelihood Program (CLP), a current World Cocoa Foundation (WCF) development program funded at US $40 million by the Bill and Melinda Gates Foundation and matching grants was implemented in 2009. The aim of CLP is to double the income of approximately 200,000 smallholder cocoa-growing households in Ghana, Côte d'Ivoire, Nigeria, and Cameroon. The objectives of CLP phase one (CLP-I), which was implemented from February 2009 to January 2014, were to: (1) improve market efficiency and build capacity of farmers and farmer organizations, (2) increase cocoa production and quality at the farm level, and (3) improve competitiveness by increasing farm diversification (Ndiaye et. al., 2013).

Farmers who participated in CLP-I were provided training on: 1) good agricultural practices, including proper application of inputs and pilot programs taught through the Farmer Field School (FFS), and 2) business and economic decision making, educating farmers on farm management, and also setting up business service centers for farmers provided through the Farmer Business School (FBS). Subsequently, farmers who were credit-worthy and had completed both FFS and FBS were extended credit through an Input Credit Package (ICP) to obtain inputs (fertilizers and agro-chemicals) for production. The ICP provided credit to purchase subsidized inputs at the beginning of the growing season, which was paid back after cocoa harvest. The focus for CLP phase two (CLP-II), which is taking place from February 2014 to January 2019, is on scaling up and building upon best practices, lessons learned, and the partnerships developed in the first phase of the program. CLP-II will also focus on improving cocoa yields, as well as food crops grown by cocoa farmers such as maize, cassava, and yams. Two recent studies on CLP have found conflicting results on the impact of CLP-I on farmer yields. Diegert et al. (2014) found no conclusive evidence that farmers who received training under CLP experienced any yield increase, while Norton et al. (2013) found that for participants in Ghana who completed all CLP training, average yield rose by 75%. This study is privy to more data than both of the previous studies and as such, sets out to estimate the potential yield, revenue and profit benefits from the implementation of CLP-I.

Thesis Objectives

Given the conflicting results of Diegert et al. (2014) and Norton et al. (2013), the goals of this two-paper thesis are to a) econometrically estimate the effects of CLP-I participation on yields and income and b) use a Farm Household model to simulate, based on the estimated yield impact, the effects of CLP-I on equilibrium prices and quantities and welfare in the cocoa export market and Ghanaian food markets for maize, rice, cassava, and yam.

The specific objectives of the first study are:

1. Develop a difference-in-difference model to econometrically estimate the effects of CLP-I participation on yields in Ghana, Cote d'Ivoire, Nigeria, and Cameroon;
2. Use new household level survey data collected from 2,048 pre- and post- CLP-I interviews of cocoa producers and more detailed micro-level data to obtain more accurate estimates of the effect of CLP-I on yield;
3. Estimate the net present value (NPV) of the estimated yield impacts over the 25 year productive life of a cocoa tree;
4. Estimate the benefit-cost-ratio for the CLP-I;

The key findings from this study are that yield enhancements attributable to farmer that receive the full CLP-I package (FFS, FBS, and ICP) are 32%, 34%, 50%, and 62% in Ghana, Côte d'Ivoire, Nigeria, and Cameroon, respectively. The NPV of the 25 year life of a cocoa tree is US $520.2 in Ghana, US $618.3 in Côte d'Ivoire, US $610.9 in Nigeria, and US $722.1 in Cameroon. Finally, the benefit-cost ratios of the program are estimated to range from US $18-US $62 for every dollar spent on human capital development.

The specific objectives of the second study are:

1. Develop a Farm Household Model (FHM) for cocoa and subsistence food farming;

2. Calibrate the FHM to Ghanaian cocoa farmers who also produce maize, cassava, and yam for subsistence consumption;
3. Use the calibrated FHM and the yield estimated based on specific objectives 1 and 2 of the first study to simulate the impact of CLP-I and demand expansion for Ghanaian cocoa on prices, quantities, and welfare in the Ghanaian cocoa market and local maize, cassava, rice, and yam food markets;
4. Conduct sensitivity analysis on
    a. farmer participation rates in CLP based on the objectives of CLP-II
    b. global cocoa demand expansion.

The second study shows that, due to increased production from CLP-I and an expansion of the demand for Ghanaian cocoa, the cocoa price rises slightly. The net welfare gains are higher for CLP households relative to non-CLP households. CLP-I increases the income of participating farmers leading to higher consumption of maize, cassava, rice, and yams. However, there are no spillover effects in the maize, cassava, and yam markets because the increase in consumption is met by an equal increase in production for these staple food items. However, because cocoa farmers do not produce rice, the increase in demand raises the price of rice. Non-CLP-I rice consumers experience a welfare lose due to an increase in price while rice producers' benefit from the higher price and increase demand by cocoa farmers. The net benefits of CLP to Ghana and the world are both positive. The sensitivity analysis shows that, ceteris paribus, as the CLP participation rate increases, the cocoa price declines. At a CLP participation rate greater than 7.75%, net gains from the program in Ghana become negative due to the declining cocoa price as supply increases. However, as world cocoa demand expands, the cocoa price rises. This has the important policy implication that, because most agricultural goods have an inelastic demand (including cocoa), marketing and demand expansion are equally as important as production expansion to increase rural farm household income.

An important contribution of this study to the literature is on impact evaluation of developmental program for cocoa farmers. The study measures not only the direct, but also the indirect impact of policies aimed at increasing farmers' income through yield enhancement extension programs in low-income countries. While many studies have evaluated the direct impact of development programs for cocoa farmers in Sub-Saharan Africa (Diegert et. al., 2014; Gockowski et. al., 2010; Norton et. al., 2013; Opoko et. al., 2009), none in the available literature have estimated their indirect impacts on external markets.

Organization

Following the introduction, the rest of the thesis is organized as follows. Chapter II presents the first paper titled "*Estimating the Impact of Farmer Field Schools in Sub-Saharan Africa: The Case of Cocoa*". Chapter III presents the second study titled "*Potential Spillover Effects of Farmer Field Schools in Sub-Saharan Africa: The Case of Cocoa*". Chapter IV provides concluding remarks.

Chapter II: Estimating the Impact of Farmer Field Schools in Sub-Saharan Africa: The Case of Cocoa

A. Abstract

This study measures the economic impact of the first phase of the Cocoa Livelihood Program (CLP-I), a current World Cocoa Foundation (WCF) project, sponsored by the Bill and Melinda Gates Foundation and aimed at improving the livelihood of over 200,000 small cocoa producers in Sub-Saharan Africa via training, crop diversification, and farmer-based organizations. Using data collected from 2,048 pre- and post- CLP-I interviews of cocoa producers in Ghana, Cote d'Ivoire, Nigeria and Cameroon, the results show that yield enhancements attributable to CLP-I are 32%, 34%, 50% and 62% in Ghana, Côte d'Ivoire, Nigeria and Cameroon, respectively. These yield enhancements have the potential to increase income by 26%, 29%, 48%, and 87% for cocoa farmers in Ghana, Côte d'Ivoire, Nigeria and Cameroon, respectively Using a total program cost of US $151- US $200 per beneficiary and estimated annual benefits of US $109 – US $322 per beneficiary over 25 years, the benefit-cost ratios are estimated to range from US $18 – US $62 for every dollar spent on human capital development. These results suggest the WCF should endeavor to increase the number of farmers who receive all, not some, of the components of the program. This would not only help ensure that each producer obtains as much human capital as possible from each of the training programs but increases the probability of reaching the CLP goal of doubling the income of 200,000 smallholder cocoa-growing households in Ghana, Côte d'Ivoire, Nigeria and Cameron.

B. Introduction

Given the limited extension services throughout Sub-Saharan Africa, many famers rely on Non-Governmental Organizations for technical and production support. This occurs in cocoa production where, for example in Ghana - the world's second largest producer of cocoa - yields declined from 1964 to 1990 because producers lacked information regarding best cocoa practices, including pruning, and the need to replace aging trees (Mahrizal, Nalley, Dixon, & Popp, 2013). Three main issues have arisen in cocoa production in Sub-Saharan Africa. First is the low cocoa yields relative to Asian countries such as Indonesia and Vietnam, which are more recent large scale cocoa producers. This discrepancy can be attributed to farmers' limited knowledge of best management practices. Secondly cocoa farmers in Sub-Saharan Africa historically have received low prices due to not understanding cocoa quality requirements. The final issue is the low or even negative returns experienced by Sub-Saharan Africa cocoa producers which can be attributed to the lack of business skills necessary to financially manage their farms. Solutions to these challenges are often offered by agricultural extension agencies.

To fill this extension gap, organizations like the World Cocoa Foundation (WCF) have implemented the Cocoa Livelihoods Program (CLP) in major cocoa growing countries of Sub-Saharan Africa – specifically Ghana, Cote d'Ivoire, Nigeria and Cameroon – to help boost productivity and income of over 200,000 smallholder cocoa-growing households in the region. CLP provides training through Farmer Business Schools (FBS) and Farmer Field Schools (FFS). Once FBS and FFS have been successfully completed, farmers gain access to credit for purchasing inputs such as fertilizer.

Two recent studies on the CLP have found conflicting results. Diegert et al. (2014) interviewed program participants and found no conclusive evidence that farmers who received training under CLP experienced any yield increase. However, the authors stated that the majority of the farmers they interviewed concluded that because of the training, they had learned improved production techniques, and this could lead to higher yields over time. Conversely, Norton et al. (2013) found that, for participants in Ghana who completed all CLP training, average yield rose by 75%. Given these conflicting results, this study seeks to analyze the effects of CLP participation on yields and income using a different estimation method and including climatic variables in the models to help explain yield variability. Specifically, the study uses paired comparisons as well as village level precipitation data.[1] While the Diegert et al. (2014) paper may on the surface indicate that CLP has not been a short run success, by ignoring the post-training intertemporal dimension of the CLP - such as the impacts of accumulated human capital acquired during training and the interaction of the multiple components in project evaluation – their results may not fully capture the total net benefits of this program. Therefore, comprehensive program evaluation approaches must be utilized when evaluating programs with multiple components such as CLP, to give future donors a comprehensive estimate of project investment returns.

With these points in mind, this study analyzes phase one of the CLP (CLP-I).[2] Using household level data collected from cocoa farmers in Ghana, Nigeria, Cote d'Ivoire and Cameroon, for both pre and post CLP, and specifying a difference-in-differences model, this study seeks to: (1) estimate the annual yield increases associated with the CLP-I, (2) estimate the net present value (NPV) of these benefits over the 25 year productive life of a cocoa tree (noting

[1] Precipitation is a major driver for flower setting and, ultimately, yields.

[2] The first phase (CLP-I) spanned from February 2009 to January 2014, and the second phase (CLP-II) should span from February 2014 to January 2019.

that while CLP-I is only funded for four years, the resulting accumulated human capital should be amortized over the productive life of the tree which, likely coincides with a farmer's use of CLP provided training), and (3) estimate the benefit-cost-ratio for the CLP-I program in each of the project's four countries.

C. Background information

1. Cocoa Production in Sub-Saharan Africa

Cocoa is the highest revenue agricultural commodity exported from Sub-Saharan Africa averaging about US $6.5 billion in 2012-11 (UN Statistics Division, 2015). Approximately 70% of the world's cocoa exports originate from the region: in 2010/11 Côte d'Ivoire accounted for 37% of world cocoa exports, followed by Ghana (24%), Nigeria (7%) and Cameroon (6%) (ICCO, 2012a). Cocoa exports account for 15% of GDP in Côte d'Ivoire, 11% in Ghana, 3% in Cameroon and 1% in Nigeria. [3] Over 90% of cocoa production in these countries is produced by about two million small scale household farms, on two-to-four hectare plots with yields ranging from 300-400kg/ha and with low levels of input usage (WCF, 2009, 2014). Cocoa accounts for 60-90% of cocoa producing household income in Sub-Saharan Africa - the majority of which live on less than US $2/day (WCF, 2012) - with a per capita daily income in 2011 estimated be in the range of US $1.09 to US$ 1.76 in nominal terms (WCF, 2012). The low cocoa producer income is a function of low productivity per hectare as well as low farm gate prices. Ghanaian cocoa farmers receive on average 73% (2002-2013) of the free-on-board price of cocoa; however, their Ivorian peers receive 40% of the free-on-board price due to export taxes imposed by the government. Other drivers of low prices in Côte d'Ivoire - the largest world cocoa

[3] Derived from cocoa export share estimates retrieved from (ICCO, 2012b) and exports of goods and services (% of GDP) estimates retrieved from the World Bank (2013).

producer - include little or no access to market information, misunderstanding of quality requirements, high transport cost, and individual rather than group selling (Wegner, 2012).

2. Impact of Structural Adjustment Programs on Cocoa

Structural Adjustment Programs (SAPs) instituted by the World Bank and International Monetary Fund in the mid-1980s led to the liberalization of the cocoa market throughout Sub-Saharan Africa. The main objective of SAPs was to improve economic efficiency by linking the domestic cocoa market to the world market through greater 'pass-though' of the world cocoa price to the farmer. Nigeria was the first to liberalize in 1986, followed by Cameroon (1994) and Côte d'Ivoire (1998-2002) with Ghana having a partially liberalized cocoa sector since 1992-1993, which is regulated by the Ghana Cocoa Board (Gilbert, 2009). Gilbert (2009) suggests that two main liberalization models have emerged in Sub-Saharan Africa via SAPs. The first is the pure liberalization model where the government is absent from the sector so farmers face low taxation but are constrained by few public services, such as agricultural extension, as is typical of Nigeria and Cameroon. The second is the partial liberalization model in which the government remains active in the sector while farmers pay significant levels of taxation but obtain a high level of services (farmer training, input subsidies, and seed distribution) as is typical in Ghana. Gilbert (2009) finds that Côte d'Ivoire sits between these two institutional structures and manages to experience all the drawbacks of liberalization without any of the potential benefits of state involvement. The reform process in Côte d'Ivoire is characterized by high export taxation, low farm gate prices, and few extension services for farmers.

Even though the liberalization process has led to increased competition in internal markets and has increased the producer's share of world prices (with the exception of Côte d'Ivoire), institutional reforms insert an additional dimension. Scaling down the activities of

Parastatals and replacing them with private institutions have led to a decline in extension services, agricultural research, and rural banking, which played an integral role in tree crop production enterprises like cocoa (Nyemeck et al., 2008; Wilcox and Abbott, 2006). [4] The absence of free or subsidized fungicides, herbicides, fertilizers, and technical training following liberalization led to declining yields and increasing revenue volatility for cocoa producers, particularly for the rural poor who live on marginalized land susceptible to weather and yield variability (Nyemeck et al., 2008). Currently, agricultural loans to cocoa farmers come in the form of input packages, primarily through programs offered to farmer based organizations. An example of this is the Cocoa Abrabopa Program in Ghana where farmers are supplied inputs (fertilizer, pesticides, and fungicides) on credit and extension services for which farmers repay the cost upon selling their crop, or through programs offered to individual farmers by Non-Governmental Organizations such as the WCF CLP-I.

3. The Formation of the World Cocoa Foundation and the Cocoa Livelihoods Program

Despite cocoa's importance in providing income for more than two million households, producers face issues such as: (1) yield loss due to pests and diseases (30% loss annually), (2) outdated farming techniques and limited availability of improved cocoa varieties, (3) limited organizational support, (4) education and health issues, and (5) labor practices which often involve children working on cocoa farms at the expense of attending school (ICI, 2011). To minimize the occurrences of these issues, a global collaboration, backed by leading firms in the world's cocoa and chocolate industries, has arisen to help ensure that cocoa producing households and their communities are able to reap sustainable benefits from cocoa farming (ICI,

[4] Parastatals is an agency owned or controlled wholly or partly by the government.

2011). As part of this collaboration, the WCF and the International Cocoa Initiative (ICI) were formed to collaborate on national plans enacted by country governments. Since 2000, WCF and ICI - in form of programs, partnerships, and foundations - have worked to: (1) increase farmer's income through training programs, crop diversification, and farmer organizations, (2) encourage sustainable cocoa farming practices, (3) eradicate child labor and improve children's access to higher quality education (ICI, 2011). The ICI was established by the "Harkin-Engel Protocol" in 2002 and works to eliminate child labor in cocoa-producing countries. The WCF was founded in 2000 to promote social and economic development and environmental stewardship in cocoa-growing communities through public-private partnerships (WCF, 2015).

In this role, the WCF created the Cocoa Livelihood Program (CLP). The aim of CLP funded at US $40 million by the Bill and Melinda Gates Foundation and Matching Grants, is to double the income of approximately 200,000 smallholder cocoa-growing households in Ghana, Côte d'Ivoire, Nigeria and Cameron. The CLP objectives are to: (1) improve market efficiency and build capacity of farmers and farmer organizations, (2) increase production and quality of cocoa at the farm level, and (3) improve competitiveness, by increasing farm diversification (Ndiaye et al., 2013). See WCF (2009) for details on key CLP-I activities. The first phase (CLP-I) of CLP had three, main training segments: first is the Farmer Field School (FFS) which educated farmers on good agricultural practices including proper application of inputs and pilot programs to increase access to high yielding cocoa varieties. Second is the Famer Business School (FBS), which focused on business and economic decision making, educated farmers on farm management, and also set up business service centers for farmers. Finally, an Input Credit Package (ICP) was the culmination of CLP-I, where individuals who were credit-worthy and had completed both FFS and FBS were extended credit to obtain production inputs.

4. Previous Cocoa Impact Studies

In 2007, Opoko et al. (2009) conducted an impact assessment of the Cocoa Abrabopa Program in Ghana under the auspices of Wienco's Farmer Based Organization and Cocoa Abrabopa Association (an organization working with cocoa farmers to improve livelihoods). Through the Cocoa Abrabopa Program, farmers were supplied extension services as well as inputs (fertilizer, pesticides and fungicides) on credit, which farmers repaid upon selling their harvest. The study utilized data on 83 non-participating farmers and 158 participating farmers collected from the 2007/08 and 2008/09 cocoa growing seasons in Ghana. The study estimated that the program resulted in a 43% revenue increase for participating farmers and a subsequent revenue to cost ratio of 2.5. The study also found that inappropriate use of inputs in terms of timing and application rates was a common production problem. Therefore, increasing farmer access to inputs solves only one part of the problem: training and other human capital investments pertaining to proper input usage are also needed.

Gockowski et al. (2010) conducted a case study of FFS implementation in Ghana and its impact on yields. Their results showed that yield enhancement attributable to FFS training was 14% per hectare for 225 randomly sampled cocoa farmers who were among some 829 cocoa farmers enrolled in 30 field schools across Ghana. They concluded that farmers achieved this 14% yield enhancement mainly by increasing their own labor input and hiring more laborers, selectively applying the set of field management (pruning, shade management, and proper phytosanitary control) techniques, and implementing human capital knowledge acquired in the training. They concluded that the FFS training had statistically significant, positive impacts on participating farmers' productivity.

Norton et al. (2013) conducted a cost-benefit analysis of a portion of CLP-I in Ghana, but from a limited sample of Ghanaian producers from one (2010/11) growing season. Their results showed that the CLP-I program in Ghana increased average cocoa yields by 75.24% per hectare. This increased yield, if incorporated into an optimal phased replanting rotation, would have increased the net present value (NPV) of cocoa by US $401.00 per hectare annually. Using a training cost of US $252 per farmer, they estimated the benefit-cost-ratio of CLP-I at 80:1. Even though the current study and Norton et al. (2013) seek to estimate yield enhancement attributable to CLP-I, they differ in methodology and the scope of the data used. As mentioned above, Norton et al. (2013) used data on only CLP-I participants from Ghana and from only one growing season (2010/11). The present study uses data from both CLP-I and non-CLP-I participants collected from both pre (2009/10) and post (2012/13) CLP-I periods across all four CLP-I countries. Unlike the Norton et al. (2013) approach, which utilized a conventional binary regression approach, this study employs a difference-in-differences model to better account for temporal effects and omitted variable/selection bias. Of importance, the Norton et al. (2013) study used 239 farmer observations from only Ghana while this study utilizes 2,048 farm level observations from Ghana, Côte d'Ivoire, Nigeria, and Cameroon to estimate CLP-I yield enhancement in each country.

Contrary to Norton et al. (2013), Diegert et al. (2014) found there was no statistical yield advantage for farmers who had completed CLP-I. For some years and countries, Diegert et al. (2014) found decreased yields for those farmers who had completed FBS training. However, for Nigeria, results showed a strong positive relationship between yields and those participants who received the full CLP package. The study does not implement paired comparisons (before and after for one individual) nor does it include weather or input use data which may account for their no increase in yields findings. The present study builds from the Norton et al. (2013) and Diegert et al. (2014) studies by introducing paired comparisons as well as village level precipitation data and input usage as control variables in measuring the economic impact of CLP-I.

D. Methodology and Data

1. CLP-I Program Packages

The CLP-I delivered its programs in four specific, conceptualized program packages (bundles of training and services) (WCF, 2011). The four packages were: (1) Full CLP-I that included FFS, FBS, and ICP (package FULLP), (2) FFS and FBS only (package FBP), (3) FFS only (package FFSP), and (4) FBS only (package FBSP). The packages were designed so that the ICP could be obtained only by creditworthy farmers who had completed both FFS and FBS. The experimental design implied by the combinations of programs allows for identifying the individual impacts of FFS or FBS, the marginal impact of FBS (FFS) given FFS (FBS) and the marginal impact of ICP given both FFS and FBS.

2. Specification of the CLP-I Impact Evaluation Model

To estimate the yield enhancement attributable to the various CLP-I packages, a semi-log, linear regression model is specified based on the difference-in-differences model in Meyer (1995), and estimated by ordinary least squares. [5] The outcome variable (Y_{it}^{j}) is the natural log of the cocoa yield of the ith farmer in period *t* measured in kg/ha, the superscripted *j* is the group designation: experimental (*j* = 1) and control group (*j* = 0). The natural log of yield is adopted to facilitate cross-country comparisons of program impacts: binary variable coefficients can readily

[5]While Meyer (1995) presents a single component intervention, in this study the CLP-I has three major components with possible interactions.

be converted into estimates of the percentage yield change attributable to these variables. This is particularly convenient for estimating the impact of the CLP-I program packages since all these variables are categorical (binary). The only continuous variables are farm size and the precipitation variables. They are entered in log form so that their coefficients are elasticities. The model can be written as:

$$LN(Y_{it}^{j}) = \alpha_0 + \alpha_1 YEAR_t + \alpha_2 TREAT^{\,j} + \boldsymbol{\beta}_0 \mathbf{PACKAGE}_t^{\,j} + \boldsymbol{\delta}_1 \mathbf{PRECIP}_t^{\,j} + \boldsymbol{\delta}_2 \mathbf{INPUTS}_t^{\,j} + \boldsymbol{\delta}_3 \mathbf{DEMO}_t^{\,j} + \boldsymbol{\delta}_4 \mathbf{LOC}_t^{\,j} + \varepsilon_{it}^{j}. \qquad (1)$$

The coefficient α_0 is a constant term. The coefficient α_1 is a time effect common to both control and experimental groups, where *YEAR* takes on the value of one in post-intervention period (t = 1) and zero in pre-intervention period (t = 0). The time effect captures how the outcome changes over time due to unobservable factors common to both groups other than the experimental intervention. The coefficient α_2 is the experimental group specific effect (average permanent differences between the experimental and control group), where $TREAT$ takes on the value of one for the experimental group and zero for the control group. The vector $\boldsymbol{\beta_0}$ is the effect of the four treatments after controlling for the effects of time and permanent differences between the experimental and control groups. The vector ***PACKAGE*** contains binary variables for the four CLP-I packages (*FULLP, FBP*, *FFSP* and *FBSP*). The i^{th} farmer in the experimental group could only be in one of the packages in the post-intervention period (*YEAR* =1).

The difference-in-differences model relies on the assumption that α_1 represents the net effect of changes in factors over time and is equal for both groups. With several years of data this assumption can be tested. The present study has only two periods, pre and post, so the common trends assumption cannot be tested directly. The model used in this study partially compensates for this shortcoming by including observable exogenous impact variables. The exogenous variables include the vector ***PRECIP*** which contains variables, *PRECIP1, PRECIP2* and *PRECIP3,* respectively, for the natural log of precipitation for the season's cumulative rainfall measured in millimeters; they include the main crop flowering, main crop maturity, and light crop maturity, respectively for the i^{th} farmer. [6] The vectors ***INPUT***, ***DEMO***, and ***LOC*** contain variables for production inputs, farmer and farm characteristics, and location, respectively. The variable ε_{it} is the customary error term with mean zero and assumed to be distributed independently of treatment status, time and among individual farmers. Because each farmer in the sample is observed twice (in pre- and post- CLP-I periods), robust standard errors are estimated that recognize the pairwise clustering for a given farmer and are robust for heteroscedasticity. Equation *(1)* is estimated separately for each of the four countries.

3. The Data

3.1 Household Data and Sampling

The household level data used in the study are secondary data. The data on qualitative and quantitative information about cocoa farmers and their production practices were collected from two surveys conducted for the WCF by third party organizations. These surveys were administered during the 2009/10 and 2012/13 cocoa growing seasons in Ghana, Nigeria, Cameroon, and Cote d'Ivoire. The 2009/10 survey was the baseline conducted by the consulting group Mathematica Policy Research in order to measure key economic and social indicators

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[6] Generally, there are two harvests of cocoa within a growing season: the main crop in October-March and the light crop in May-August (CRIG, 2010). Cumulative precipitation for the main crop flowering and maturation periods was measured as the precipitation from the preceding January through May, and preceding June through October, respectively. For the light crop, cumulative precipitation for the main crop flowering and maturation periods was measured as the precipitation from the preceding June through October, and preceding December through March, respectively.

before the CLP-I implementation. The 2012/13 survey was conducted by IPSOS Public Affairs for the impact analysis at the completion of the CLP-I, and as a baseline for CLP-II.

Households were selected for the 2009/10 survey using a two-stage procedure; first, villages were randomly selected into the treatment and control clusters (64 villages in Côte d'Ivoire, 99 villages in Ghana, 40 villages in Cameroon, and 40 villages in Nigeria). Households in each village were then randomly ordered and visited based on the random ordering. During these visits, the survey firm assessed eligibility and conducted interviews until the desired number of interviews had been completed in each village. Eligibility was based on criteria for the CLP-I farmer training interventions. In Ghana and Côte d'Ivoire, eligible cocoa farmers had to be 18 to 55 years old and have managed a farm of at least one hectare. In Nigeria and Cameroon, age eligibility criteria differed, with upper limits of 76 and 65 years, respectively. To ensure that female cocoa farmers were represented in the sample from all countries, they were prioritized in two ways: (1) the female having the largest farm was selected in every household with an eligible female cocoa farmer and (2) data collection firms were mandated to interview a minimum number of female cocoa farmers in each village, hence households were randomly selected until a female cocoa farmer was identified and interviewed (see Fortson et al. (2011) for more sampling detail). For the 2012/13 survey, farmers were chosen at random from the baseline sample. However, the oversampling of female farmers applied in the 2009/10 survey continued in the 2012/13 sampling.

The total sample size was 2,048 usable responses consisting of 1,024 farmers surveyed in both pre- and post- CLP-I. Given that CLP-I was in its implementation stage during the baseline survey, it is assumed that reported yields in the pre-CLP-I phase were not influenced by the program. The relevant survey data used were: farmer location, farmer and farmer household characteristics, farm size in hectares, cocoa productivity in kg/ha, and inputs used in production (chemical fertilizers, fungicides, herbicides, insecticides, and labor) which were binary (yes or no to the usage of specific inputs in the last twelve months). Respondent participation in the various CLP-I programs was also recorded. Data on yields and farm size were self-reported by farmers. Data on input usage were again binary without the timing and quantities of these inputs used. Also, farmers were not asked about the age and replacement rates of cocoa trees on their farm which precluded accounting for the influence of tree age on cocoa yield.

The randomness of village and farmer selection into or out of the CLP-I is important for obtaining valid results from the difference-in-differences model in reference to the common trends assumption. With randomness of village and participants being treated or not, the common trends assumption is plausible implying valid inference from the model. It must also be recognized that the sample, because of eligibility requirements, oversampling of female farmers and restrictions to certain geographical areas in each country, cannot be viewed as a simple random sample of all cocoa farmers in the respective countries.

3.2 Precipitation

This study uses daily precipitation data (mm) collected from AWhere (2014) at the village level for both 2009/10 and 2012/13 cocoa growing seasons to get the three precipitation variables for each village. These data were available at about 9 km^2 grid cells. The weather data were collected by a combination of global meteorological, on-the-ground stations and orbiting weather satellites. The advantage for this study of using data at this resolution was that individual villages had unique weather data unless multiple villages were contained within the same 9 km^2 grid cell. However, weather data were available for only Ghana and Côte d'Ivoire.

3.3 Descriptive statistics for the dependent and independent variables

Descriptive statistics of the dependent and independent variables are presented in Table A1 in the appendix, provided as supplemental material to the study. Average cocoa yield, aggregating across growing seasons, CLP-I participation, and across all four countries was estimated at 383kg/ha. Average cocoa yield was higher in the 2012/13 growing season (446.2 kg/ha) relative to the 2009/10 season (293.3 kg/ha) with the highest average 2012/13 yields recorded in Nigeria (914.4 kg/ha), followed by Côte d'Ivoire (425.2 kg/ha), Ghana (420.0 kg/ha) and Cameroon (284.6 kg/ha). The average farm size across all countries for the two seasons was estimated at 3.7ha; the largest average farms were recorded in Cameroon at 4.1ha, followed by Côte d'Ivoire (3.8ha), Ghana (3.7ha), and Nigeria (3.1ha). Inorganic fertilizer usage for the 2012/13 season was highest in Ghana and Nigeria at 33%, and followed by Côte d'Ivoire (20%) and Cameroon (9%). Fifty-five percent of the sample farmers were CLP-I participants; 44%, 51%, 64% and 84%, respectively, in Ghana, Côte d'Ivoire, Nigeria and Cameroon. Package exposure shows that the FFS-only package had the highest proportion in terms of package exposure at 38%, this is followed by the Full package (having received FFS and FBS training as well as ICP) at 13% and then the FBS only package at 4%. Also, the proportion of the Full package exposure was highest in Cameroon at 30%, and followed by Nigeria at 28%, Côte d'Ivoire at 8%, and Ghana at 7%. Even though the number of observations is large, for a given treatment in a given country the number of observations can be less than thirty. Hence some treatments that are found insignificant in the sample might have been significant if the sample size for that retreatment was greater. [7]

[7] The study uses t-statistics for our hypothesis testing, which are appropriate in small samples, as opposed to z-statistics.

The study had a total of 44 districts in the sample: 18 from Ghana, 15 from Nigeria, 6 from Côte d'Ivoire, and 5 from Cameroon. Graphical representations of villages in study areas are presented in Figure A1 in the appendix. Mean, cumulative precipitation levels in Ghana were estimated at 334.5mm, 605.1mm and 114.0mm for the main crop flowering (PRECIP1), main crop maturation (PRECIP2) and light crop maturation (PRECIP3) periods, respectively. Mean seasonal cumulative precipitation levels in Côte d'Ivoire were estimated at 370.8mm, 572.0mm and 108.1mm for PRECIP1, PRECIP2, and PRECIP3, respectively.

Tests of baseline farm size and yields between the treatment and control groups show that within each of the four countries, farmers in the control and treatment groups essentially manage farms of a similar size and similar cocoa productivity levels. Farmer demographics vary little between the treatment and control groups. Between control and treatment groups farmers are equally likely to be women or men and have similar educational experiences, except in Côte d'Ivoire where the control group had 7% more women and lower education than the treatment group. In Ghana, both groups are equally likely to use the same inputs. Since there appear to be no substantial differences in mean characteristics between the treatment and control groups, the common trends assumption is less of a concern (see Table A2 in the supplemental material for full results comparing control and treatment groups).

4. Net Present Value

Given the estimated yield increases from the full CLP-I package (FULLP) in each country shown by equation *(1)*, a Net Present Value (NPV) of total benefits can be calculated using the methods implemented in Mahrizal et al. (2013). [8] To comprehensively measure the

[8] Mahrizal et al. (2013) solve for the optimum replacement rate (ORR) and initial replacement year (IRY) of cocoa trees that maximize a 50-year NPV for a one-hectare, Ghanaian cocoa farm

costs and benefits of CLP-I, which likely extend beyond the project life span, a NPV model was implemented to predict the intertemporal net benefits resulting from human capital investments. By calculating intertemporal benefits over twenty-five years, the holistic economic return on CLP-I can be estimated. The Mahrizal et al. (2013) approach is used in this study to calculate the maximum NPV for both pre- and post- CLP-I intervention periods. Given the annual, optimum replacement rate (ORR) of trees in an orchard and initial replacement year (IRY) estimated by using the methods implemented in Mahrizal et al. (2013), the annual NPV is estimated as a function of projected cocoa prices, costs of labor and inputs, inflation rate, and discount rate. The NPV per hectare is estimated as the sum of the discounted (Net Future Value) NFV in each year using a 25-year, parabolic shaped average lifecycle yield curve of a cocoa tree in Ghana, based on research conducted by the International Institute of Tropical Agriculture (IITA) (see Figure A2 in supplemental material). Using the optimal ORR and IRY which maximize NPV, a baseline NPV was estimated as the maximum potential profit per hectare that cocoa farmers could achieve given current production practices without any CLP-I package. It is assumed that cocoa farmers behave rationally to maximize their profits before the CLP-I program was implemented. However because of a number of real-world constraints — including access to credit to buy fertilizer — cocoa farmers' most likely do not actually maximize their profit using the optimum replacement of cocoa tress. To control for the farmer behavioral effect in estimating CLP-I

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by employing a phased replanting approach. Using cocoa production data collected by the Sustainable Tree Crop Program (STCP) and International Institute of Tropical Agriculture (IITA), the study found that the annual ORR and IRY are 5%–7% and 5-9 years, respectively, across the three production systems studied: (1) Low Input, Landrace Cocoa, (2) High Input, No Shade Amazon Cocoa, and (3) High Input, Medium Shade Cocoa. The authors estimated economic gains that exceed currently practiced replacement approaches by 5.57%–14.67% across production systems.

benefits, it is necessary to assume farmers behave in the same way in terms of economic goals so as not to confound that impact of CLP-I with adopting a better optimizing strategy at the same time.

The Low Input Landrace Cocoa (LILC) production system described in Afari-Sefa et al. (2010) and Gockowski et al. (2011) was assumed as the baseline production practice; this system uses unimproved local landrace cocoa varieties with moderate shade levels. There are three key assumptions. First, farmers use pesticides and fungicides but no inorganic fertilizer in the baseline scenario. Second, once credit-worthy farmers complete FFS and FBS, they can access input credit which translates to inorganic fertilizer usage and increased production costs. The model cost structure is adjusted accordingly so CLP-I graduates implement the High Input Medium Shade Cocoa (HIMSC) production system, as described in Afari-Sefa et al. (2010). As a result, input costs increase by 37.7% annually (estimated as the additional cost associated with CLP-I fertilizer credit package). The adjustment allows for more accurate estimation of profit because the large yield increases attributable to CLP-I imply higher production costs.[9] Finally, it is assumed that the yield enhancement estimated in equation *(1)* attributable to the full CLP-I package (FULLP) is a constant percentage gain relative to those cocoa producers not exposed to FULLP (baseline scenario).

The NFV and NPV for the 25-year productive life of the cocoa trees per hectare were estimated as follows:

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[9] Afari-Sefa et al. (2010) and Gockowski et al. (2011) estimated costs and returns for one hectare of unimproved cocoa planted at 3 x 3 m spacing (1,100 plants per hectare) with no nursery cost for LILC and HIMSC. The only difference between the cost estimates of LILC and HIMSC is the use of inorganic fertilizer.

$$NFV_{jt} = \left[YIELD_{jt}\left(1 - g_j\right) . P_{jt}\left(1 + r_{jt}\right)\right] - C_{jt}\left(1 + r_{jt}\right)^t, \quad (2)$$

$$NPV_j = \sum_{t=1}^{25} NFV_{jt} / \left(1 + r_{jt}\right), \quad (3)$$

where $YIELD_{jt}$ is the yield in kg/ha of cocoa in period t for a given hectare for country j and depends upon the age of trees on that hectare, as shown in Figure A2. The variable g_j is the yield enhancement attributable to the full package (*FULLP*) for country *j*. The expressions $P_{jt}(1+r_{jt})^t$ and $C_{jt}(1+r_{jt})^t$ are the cocoa price and cost of cocoa production in period t in country j, compounded by country *j's* inflation rate r_{jt}, respectively. The variable r_{dj} is country *j's* discount rate. Dividing equation *(3)* by 25 (the average productive life of a cocoa tree) gives the annual average NPV of profit per hectare for each country. Like Tisdell and Silva (2008), this study assumes no salvage value for cocoa trees in the NPV. The baseline daily wage for labor was fixed at US $2.2, US $2.6, US $3.9, and US $2.0, respectively, for Ghana, Côte d'Ivoire, Nigeria, and Cameroon, as per the 2011 daily minimum wage retrieved from ILO (2012). The insecticide and fungicide prices for Ghana were respectively fixed at US $10.4/liter and US $1.1/sachet (Gockowski et al., 2011), the fertilizer price was taken as the price farmers paid for the CLP-I fertilizer credit package, which is estimated at US $11.6/50kg (Antista, 2014), and the costs of all other inputs and materials were taken from Afari-Sefa et al. (2010) and Gockowski et al. (2011); all prices given above are in term of real 2010 dollars. Using the yield, cost, and inputs outlined in Afari-Sefa et al. (2010) and Gockowski et al. (2011) and the optimal ORR and IRY estimated by Mahrizal et al. (2013), the baseline NPV was estimated at $g_j = 0$.

Given that the Ghana Cocoa Board marketing board sets the cocoa price in Ghana, the farm gate price for Ghana was set at 77.81% of the net free-on-board price; the share of the farmers' price was estimated as the average for the 2010/13 period obtained from Government of

Ghana (2010). For Côte d'Ivoire, Nigeria, and Cameroon, the farm gate price as a share of the free-on-board price was set at 49.0%, 74.1%, and 73.5%, respectively, per the 2000/11 period annual averages retrieved from ICCO (2012b). The free-on-board price for all four countries was set at the average ICCO price of US $3.5/kg observed in January, 2010 (ICCO, 2015).

Unlike Ghana, where it was possible to obtain data on input prices, cost, and yield curves for both the LILC and HIMSC production systems, no such data were available for Côte d'Ivoire, Nigeria, and Cameroon. Thus prices, cost, and yields for both the LILC and HIMSC production systems were estimated for the three other countries using the data available for Ghana. Price Level Indexes (PLI) obtained from World Bank (2011) were used to estimate non-labor input prices for Côte d'Ivoire, Nigeria, and Cameroon using the data available for Ghana. [10] Using PLIs obtained from World Bank (2011), the PLIs for Côte d'Ivoire, Nigeria, and Cameroon were estimated at 104.6, 104.5, and 104.1, respectively (Ghana=100).

Lifetime yield curves for Côte d'Ivoire, Nigeria, and Cameroon were estimated by adjusting the Ghanaian yields obtained from Afari-Sefa et al. (2010) and Gockowski et al. (2011) by multipliers estimated from country fixed effects regressions for yield using annual country yield data retrieved from FAO (2015) for the period 1993-2012. The regressions were estimated as:

$$\text{LNYIELD}_{jt} = \beta \mathbf{X}_{jt} + \gamma \mathbf{Z}_{jt} + v_t, \qquad (4)$$

[10] PLIs are standardized indexes expressing the price level of a given country relative to another. They are estimated by dividing a country's Purchasing Power Parity by its respective dollar exchange rate. Countries with PLIs less than 100 have price levels that are lower than that of the base country and PLIs greater than 100 have price levels that are higher than that of the base country. Generally, PLIs are preferred to exchange rates when comparing because PPPs evolve slowly, whereas exchange rates can change quickly (World Bank, 2014).

where *LYIELD* is the natural log of country *j*'s cocoa yield in time *t*, ***X*** is a vector which contains dummy variables indicating the country (Côte d'Ivoire, Nigeria, and Cameroon with Ghana acting as the control country). The vector ***Z*** includes an intercept term, a trend variable, autoregressive terms, and structural dummies that are hypothesized to influence yield. The multipliers were computed as the exponentiated value of the estimated coefficients on the respective country's dummy variable. The yield curve generated for each country is provided in Figure A2 while the calibrated unit cost of inputs and the yield multipliers are presented in Table A3. Inflation rates of 10.1%, 2.8%, 11.3%, and 2.2% per year, respectively, for Ghana, Côte d'Ivoire, Nigeria, and Cameroon, as given by the 2010/13 average (African Development Bank, 2014), are used to project the prices of labor and inputs. The discount rates were held constant at 11.7%, 3.5%, 7.1% and 3.2% per year, respectively, for Ghana, Côte d'Ivoire, Nigeria, and Cameroon, as per the 2010/13 annual average deposit rate (IMF, 2014).

5. Benefit Cost Ratio

The benefit-cost-ratio of CLP-I can be estimated as:

$$\mathrm{BCR}^{j}_{\mathrm{CLP\text{-}I}} = \left(\mathrm{NPV}^{j}_{\mathrm{CLP\text{-}I}} - \mathrm{NPV}^{j}_{0}\right)/\mathrm{C}_{\mathrm{CLP\text{-}I}}\,, \qquad (5)$$

where $\left(NPV^{j}_{CLP\text{-}I} - NPV^{j}_{0}\right)$ is the difference between the baseline NPV (no training) and the post CLP-I NPV (with *FULLP*). The estimated NPV for country *j* estimated from equation *(3)* is in US \$/ha. The variable $\mathrm{C}_{\mathrm{CLP\text{-}I}}$ is the total cost of CLP-I per beneficiary, which is assumed to occur at time t = 0 (2009/10). The total cost of CLP-I per farmer who benefited directly from the program was estimated at US \$151, US \$128, US \$200, and US \$130 (all in 2010 terms), respectively, in Ghana, Côte d'Ivoire, Nigeria, and Cameroon.

E. Results

1. Regression Results for CLP-I Impact

The regression estimates of equation *(1)* are displayed in Table 1 for all four countries. The coefficients of determination (R^2) range between 0.454 (Nigeria) to 0.200 (Côte d'Ivoire) reflecting the cross-sectional nature of the samples. The results for all four countries indicate that there are no clear, detectable systematic differences between the control group and the experimental group as evidenced by the insignificance of the *TREAT* coefficient. Of the four CLP-I packages, only FULLP was consistently significant ($p<0.05$ or less) in all four counties, with an associated yield increase of approximately 32%, 34%, 50%, and 62%, respectively, in Ghana, Côte d'Ivoire, Nigeria, and Cameroon. Farmers exposed to the FULLP in all four countries have increased yields compared to farmers who were not exposed to the FULLP package. Possible reasons why FFSP and FBSP are not statistically significant include: (1) FFS package only teaches good agricultural practices to farmers and apparently does not increase yields without additional input use. The FFS focuses on increased adoption of good production practices that enable farmers to better manage their cocoa farms. The immediate impact of FFS should be improved production skills enabling cocoa farmers to better manage their farms through fertilizer use and prevention of pest and disease (Nalley, 2013). (2) FBS does not focus on increasing cocoa yields but rather increasing the adoption of good business practices among farmers. This FBS emphasis should help shift the farmers' perceptions from farming as a lifestyle to farming as a business and, consequently, have less of a direct effect on yield. A Wald test of the hypothesis that the coefficients of FULLP were equal across countries did not reject the homogeneity of FULLP coefficients ($p > 0.10$) across all four countries.

During the main crop flowering period in Ghana, precipitation (PRECIP2) increased yield by 0.44% for every 1% increase in daily precipitation. In Ghana the weather variables (PRECIP1 and PRECIP3) were insignificant. None of the weather variables (PRECIP1, PRECIP2 and PRECIP3) were significant in Côte d'Ivoire. This general lack of significance is surprising and suggests that more research is necessary to better identify how weather variables should be formulated to identify weather's impact on cocoa yield. Nonetheless, research done by Faisal (1969) on cocoa yield from a large-scale experiment over seven years in Ghana suggests that there is a positive association between yield and rainfall during the periods mid-February to mid-April, from July to mid-October and at the beginning and end of the year, but a negative association during other periods.

Farm size was consistently significant ($p < 0.01$) in all four countries. For every 1% increase in farm size, production decreased by no less than 0.28%. The fertilizer variable was significant ($p < 0.1$ or less) with associated yield increases of 21%, 22%, 25%, and 19% in Ghana, Côte d'Ivoire, Nigeria, and Cameroon respectively, given the application of inorganic fertilizer. The use of pesticides was significant ($p < 0.01$) in only Côte d'Ivoire with associated yield improvements of 26%. The herbicide variable was significant in only Nigeria ($p<0.1$) with associated yield increase of 34%. The labor variable was significant in Ghana ($p<0.05$), Côte d'Ivoire ($p<0.1$), and Cameroon ($p<0.01$), with associated yield increases of 15%, 12%, and 34%, respectively. These relationships (between yield and farm size as well as yield and labor) are not surprising given that the farmers in the sample have small farms averaging 3.7ha. Benjamin (1995) argues that the relationship between cocoa yield and farm size may be a result of labor market imperfections. As an example, Teal et al (2006) indicate that small holder farmers can only employ their labor on their own farms because of limited opportunities to be employed and paid on relatively larger farms, hence yields tend to be higher on smaller farms because the farmers have more labor per hectare. Also, Teal et al (2006) rejected the hypothesis that labor inputs increase proportionally with farm size.

Table 1: Regression estimates of CLP-I effects (equation *(1)*)

Country	GHA	CDI	NGR	CAM
Time Effect, Treatment Group				
YEAR (2012/13 = 1)	0.35***	0.18	0.33**	-0.17
TREAT (CLP-I participant = 1)	0.05	0.03	0.04	-0.09
CLP-I packages				
FULLP (yes = 1)	0.27**	0.30**	0.40*	0.48**
FFSP (yes = 1)	-0.05	0.06	0.05	0.15
FBSP (yes = 1)	-0.16		0.39**	
Natural log of mean precipitation				
PRECIP1	-0.07	0.09	-	-
PRECIP2	0.44**	-0.09	-	-
PRECIP3	0.02	-0.02	-	-
Production inputs				
Natural log of farm size	-0.32***	-0.28***	-0.30***	-0.31***
Inorganic fertilizer (yes = 1)	0.19***	0.20***	0.22*	0.17*
Pesticide (yes = 1)	0.04	0.23***	0.33	0.02
Herbicide (yes = 1)	-0.01	0.02	0.29***	-0.04
Hired labor (yes = 1)	0.14***	0.11*	0.03	0.29***
Household labor (yes = 1)	0.05	0.23***	0.09	0.01
Farmer and farm characteristics				
Farmer gender (male = 1)	0.14**	0.06	-0.1	0.01
EDU (Formal education = 1)	0.01	-0.04	0.09	-0.18
Member of a farmer organization (yes = 1)	0.09*	0.15**	0.04	0.1
Improve variety (yes = 1)	-0.05	0.04	-0.24	-0.05
Pruning (yes = 1)	-0.08	-0.08	0.28**	-0.01
MLC (missing light crop = 1)	-0.45**	0.03	-0.45*	-0.41***
Constant	2.74	5.47***	5.14***	5.79***
Regression Statistics				
Sample Size	700	800	242	304
No. Clusters	350	400	121	152
R-Square	0.337	0.200	0.454	0.286
Districts	18	6	15	5

Dependent variable is the log of cocoa yield in kg/ha.
Standard errors adjusted for clustering at farmer level since each farmer is present twice in the sample and for robustness against heteroskedasticity.
Significance levels: * $p<0.10$, ** $p<0.05$, *** $p<0.01$.

Farmers exposed to the full CLP-I package (FULLP) not only have access to input credit, but are also able to tap into the knowledge base obtained from both FFS and FBS. This gives a nice interpretation of the FULLP coefficient that the additional increase in yield is due to having access to both input and training (human capital investments pertaining and proper input usage). Thus a Ghanaian farmer will have a yield increase of 21% for using fertilizer; however having been exposed to the full CLP-I package (FULLP), the same farmer will have an additional 32% increase in yield on top of the 21%. This confirms Opoko et al. (2009) argument that increasing farmer access to inputs is only one part of the solution; training and other human capital investments pertaining to proper input usage are also needed.

2. Estimated Returns to the CLP-I

Table 2 presents the annual NPV estimates for the yield increase associated with exposure to the full CLP-I package (FULLP) across the four countries in Table 1. Using the procedure developed by Mahrizal et al. (2013), the optimum replacement rate (ORR) of cocoa trees in all four countries was estimated to range between 5%-6%. The optimal initial replacement year (IRY) ranges from year 7 to year 8 in Ghana, Côte d'Ivoire, and Cameroon and it is year 4 in Nigeria. The differences in IRY and ORR across the four countries are partly due to the differences in inflation rates and discount rates. Nigeria has the lowest IRY because its inflation rate is higher than its discount rate and, therefore, it is more beneficial to attain steady-state (a state in production when revenues become stable over time) quickly. Given the optimal ORR and IRY in each country, the annual, average NPV for 25 years associated to exposure to the full CLP-I package were estimated at US $520.2, US $618.3, US $610.9, and US $722.1 respectively for Ghana, Côte d'Ivoire, Nigeria, and Cameroon. These NPVs were 26%, 29%, 45%, and 81% above the baseline NPV in their respective countries. It should be noted that these results were calculated on the assumption that relative input and output prices remain constant except for inflation and yield enhancements attributed to receiving training do not diminish or increase with learning-by-doing over time. Also, given that such a large percentage of cocoa is produced in Sub-Saharan Africa, increasing supply could place downward pressure on prices, thereby reducing the NPVs below those calculated here. Furthermore, other issues such as the introduction of new diseases or changes in weather patterns could also substantially impact yields and prices and thereby NPVs. Thus, results presented here can be viewed as estimates given today's markets prices and production environment.

Table 2: Summary of Net Present Value (NPV) and percentage change in NPV over one production cycles (25 years) with estimated yield increases from CLP-I.

Country	CLP-I Yield Increase (%)	IRY (ORR)	Baseline NPV[a] (US $)	CLP I NPV[b] (US $)	NPV Change (%)	CLP I Cost/ Farmer[c] (US $)	Benefit-cost-ratio
GHA	31.6	8, (5.9)	10,294.8	13,006.1	26.3	151.0	18.0
CDI	34.4	8, (5.9)	12,012.2	15,457.8	28.7	128.0	26.9
NGR	49.7	4, (5.8)	10,538.2	15,273.2	44.9	200.0	23.7
CAM	62.1	8, (5.9)	9,999.4	18,052.2	80.5	130.0	61.9

[a] Modeled after Low Input Landrace Cocoa (LILC) in Afari-Sefa et al. (2010).
[b] Modeled after High Input Medium Shade Cocoa (HIMSC) in Afari-Sefa et al. (2010), which includes 37.7% increased input costs per year,
[c] Estimated beneficiaries exclude the additional 20,000 farmers trained through the matching grants.
IRY is in years and ORR is in percentage; both estimated using methods implemented in Mahrizal et al. (2013).

If all 196,735 program participant farmers (Ghana (69,270), Côte d'Ivoire (52,515), Nigeria (42,739) and Cameroon (32,211)) from all four countries experienced our estimated gain in NPV associated with CLP-I, there would be a total annual gain in NPV of approximately US $33,220,715, the highest being in Cameroon (US $10,375,575) followed by Nigeria (US $8,094,887), then Ghana (US $7,512,442), and finally by Côte d'Ivoire (US $7,237,811). The estimated increase in annual NPV from the CLP-I program across all four countries averages an annual NPV increase of US $169 per beneficiary farmer. If the two million cocoa producing households living in rural areas were to realize the benefits of full CLP-I, instead of just the

196,735 participants, supply effects would likely lower cocoa prices and the resulting benefit per farmer.

3. Benefit-Cost Ratio

The results presented in Table 2 show that the estimated NPV increase generates estimated benefit-cost-ratios for a 25 year period of 18:1, 27:1, 23:1 and 62:1 for Ghana, Côte D'Ivoire, Nigeria, and Cameroon, respectively. These ratios imply that every dollar spent on human capital development could result in US $18.0, US $26.9, US $23.7, and US $61.9 increases in NPV for participating cocoa producers in Ghana, Côte d'Ivoire, Nigeria, and Cameroon, respectively.

Like Norton, et al. (2013), these estimates are conservative in a number of ways. First, program training costs have decreased over time as training mechanisms have become more efficient. Norton et al. (2013) estimated the cost of CLP-I per beneficiary at US $252 which is 66% higher than this study's estimate of US $151, given that more farmers have been reached since the Norton et al. (2013) study. Second, the estimated NPVs are on a per hectare basis; hence, while the cost of the CLP-I is fixed, the benefits may increase for farms larger than a hectare. For example, if all cocoa farmers were assumed to have 1.5 hectares, the return on human capital investment would then be estimated at US $61.0, US $87.3, US $61.9, and US $131.4, respectively, for Ghana, Côte d'Ivoire, Nigeria, and Cameroon. The estimates are not conservative if the impact of a larger supply of cocoa causes a price decrease. A sensitivity analysis of the CLP-I estimated benefit-cost-ratios in Table 3 indicates that the estimated minimum yield increase that farmers would have to achieve in order to have their estimated NPV cover the full cost of the program is 17%, 19%, 35%, and 16%, respectively, for Ghana, Côte d'Ivoire, Nigeria, and Cameroon.

Table 3: Sensitivity analysis of the CLP-I estimated benefit cost ratio

Yield Increase	NPV (US $)	NPV Change (%)	Benefit-cost-ratio	NPV	NPV Change (%)	Benefit-cost-ratio
			GHA			CDI
Baseline[a]	10,294.8	0.0	0.0	12,012.2	0.0	0.0
CLP-I[bd]	13,006.1	26.3	18.0	15,457.8	28.7	26.9
75% of CLP-I[d]	11,666.3	13.3	9.1	13,685.7	13.9	13.1
Breakeven [c] (%)			16.5			18.3
			NGR			CAM
Baseline[a]	10,538.2	0.0	0.0	9,999.4	0.0	0.0
CLP-I[bd]	15,273.2	44.9	23.7	18,052.2	80.5	61.9
75% of CLP-I[d]	11,522.2	9.3	4.9	15,402.0	54.0	41.6
Breakeven[c] (%)			34.5			15.8

Note:
[a] Denotes estimate for pre CLP-I scenario, modeled after Low Input Landrace Cocoa (LILC) production system.
[b] Denotes estimate for post CLP-I scenario, modeled after High Input Medium Shade Cocoa (HIMSC) production system.
[c] Denotes yield increase necessary to make the benefit-cost-ratio equal to one.
[d] Estimate includes 37.7% increased input costs per year due to introduction of inorganic fertilizer.

This study's results indicate that the estimated CLP-I yield enhancement appears to be robust given the magnitude of the difference between the yield increase for the break-even scenario and the CLP-I for all four countries (Ghana; 19%, Côte d'Ivoire; 10%, Nigeria; 10% and Cameroon; 65% in Table 3)

F. Conclusion and Recommendations

Using data from 2,048 on-the-ground farm observations in Ghana, Côte d'Ivoire, Nigeria, and Cameroon, from pre- and post- CLP-I intervention periods (2009/10 and 2012/13 growing seasons) and applying a difference-in-differences estimation method, this study estimated yield enhancements attributable to the CLP-I, a current WCF project aimed at doubling the income of cocoa-growing households in Sub-Saharan Africa. Using the estimated yield enhancements, a NPV model was used to estimate the value of CLP-I over the 25-year lifecycle yield curve of a cocoa tree. The results from the difference-in-differences estimation of yield enhancements attributable to CLP-I were 32%, 34%, 50%, and 62% per hectare annually in Ghana, Côte d'Ivoire, Nigeria, and Cameroon, respectively. The results indicate that every dollar spent on human capital development via the CLP-I resulted in producer gains of US $18.0, US $26.9, US $23.7, and US $61.9 in Ghana, Côte d'Ivoire, Nigeria, and Cameroon, respectively.

Institutional reforms during SAPs in Sub-Saharan Africa and the subsequent liberalization of cocoa markets have resulted in decreased levels of public goods such as research and extension. This research suggests that such public goods for cocoa producers in Sub-Saharan Africa, whether they come from governments or Non-Governmental Organizations, can be highly cost effective and increase annual income for these cocoa producers by at least 19%. The study also provides the evidence that CLP-I participants who were exposed to the full package (FFS, FBS, and ICP) had the greatest increase in cocoa productivity. While 88% of the program participants in Cameroon were exposed to the full package, only 15% of the participants in Ghana and Côte d'Ivoire received the full package. Therefore, WCF could attempt to increase these percentages in order to achieve its goal of helping as many small scale farmers as possible.

The results from this study can be used as empirical evidence to encourage prospective donors to developmental programs the potential of skill attainment to alleviating poverty, especially those aimed at targeting groups that live in small, rural, impoverished households and thrive on US $1.25 or less per day. While the CLP goal of doubling the income of its participants would at the moment seem to be falling short by the estimates derived in this paper (an increase of 32%-62%) it should be emphasized that the gains are statistically significant and substantial. Furthermore, the benefit-cost ratios for the CLP range from 18.0 to 61.9, a large return on investment by any standard. Finally, any benefits associated with CLP-II (which began in January 2014 and runs through January 2019) have yet to be realized.

The analysis has two limitations that subsequent studies could overcome. First, most input observations have only binary values. Having observations on each input amount would lead to a more precise understanding of input impact on yield. Second, because the sampling frame employed by the two surveys used in this study was aimed to be representative of CLP training-eligible farmers in the study areas, the samples used in this study do not reflect nationally representative samples of cocoa farmers in the study countries making our nationwide benefit estimates less precise than a truly random sample would. Finally, the panel data were only over two time periods and the precision of the increase in productivity estimates would likely be enhanced by additional time periods.

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Appendix: Supplemental Material

Table A1: Descriptive statistics for regression variables

	GHA		CDI		NGR		CAM	
	Pre	Post	Pre	Post	Pre	Post	Pre	Post
Sample	350	350	400	400	121	121	152	152
Yield[ab] (kg/ha)	289.88 (187.67)	420.03 (291.41)	284.56 (210.5)	425.18 (315.46)	376.75 (232.63)	914.42 (691.38)	265.26 (124.47)	284.61 (145.13)
Farm size (ha)	3.68 (2.99)	3.68 (2.99)	3.79 (2.90)	3.79 (2.90)	3.12 (2.68)	3.12 (2.68)	4.12 (2.68)	4.12 (2.68)
YEAR (2012/13 = 1)	-	1.00 (0.00)	-	1.00 (0.00)	-	1.00 (0.00)	-	1.00 (0.00)
TREAT (Experimental = 1)	0.44 (0.50)	0.44 (0.50)	0.51 (0.50)	0.51 (0.50)	0.64 (0.48)	0.64 (0.48)	0.84 (0.37)	0.84 (0.37)
No CLP package (yes = 1)	1.00 (0.00)	0.56 (0.50)	1.00 (0.00)	0.49 (0.50)	1.00 (0.00)	0.36 (0.48)	1.00 (0.00)	0.16 (0.37)
FULLP (yes = 1)	-	0.07 (0.25)	-	0.08 (0.26)	-	0.28 (0.45)	-	0.30 (0.46)
FFSP (yes = 1)	-	0.34 (0.47)	-	0.43 (0.50)	-	0.13 (0.34)	-	0.55 (0.50)
FBSP (yes = 1)	-	0.04 (0.20)	-	-	-	0.22 (0.42)	-	-
PRECIP1 (mm)	368.86 (56.14)	300.23 (111.44)	393.68 (81.84)	348.00 (47.43)	-	-	-	-
PRECIP2 (mm)	578.56 (86.22)	631.71 (96.66)	654.45 (87.82)	489.54 (129.66)	-	-	-	-
PRECIP3 (mm)	154.45 (23.90)	73.54 (64.47)	171.04 (65.22)	45.14 (29.57)	-	-	-	-

[a] Denotes estimates that exclude observations with missing light crop.
[b] Denotes the dependent variable.
Standard deviations are in parenthesis

Table A1: Descriptive statistics for regression variables (Cont.)

	GHA		CDI		NGR		CAM	
	Pre	Post	Pre	Post	Pre	Post	Pre	Post
Inorganic fertilizer (yes = 1)	0.49	0.33	0.11	0.20	0.08	0.33	0.05	0.09
	(0.50)	(0.47)	(0.31)	(0.40)	(0.28)	(0.47)	(0.22)	(0.28)
Pesticide (yes = 1)	0.81	0.92	0.53	0.66	0.94	0.95	0.89	0.91
	(0.40)	(0.27)	(0.50)	(0.47)	(0.23)	(0.22)	(0.32)	(0.28)
Herbicide (yes = 1)	0.31	0.55	0.25	0.35	0.27	0.54	0.17	0.44
	(0.46)	(0.50)	(0.43)	(0.48)	(0.45)	(0.50)	(0.38)	(0.50)
Hired labor (yes = 1)	0.61	0.76	0.6	0.43	0.84	0.97	0.61	0.61
	(0.49)	(0.43)	(0.49)	(0.50)	(0.37)	(0.18)	(0.49)	(0.49)
Household labor (yes = 1)	0.51	0.98	0.46	0.95	0.69	0.88	0.63	0.97
	(0.50)	(0.15)	(0.50)	(0.22)	(0.47)	(0.32)	(0.48)	(0.16)
Farmer gender (male = 1)	0.56	0.56	0.90	0.90	0.84	0.84	0.89	0.89
	(0.50)	(0.50)	(0.30)	(0.30)	(0.37)	(0.37)	(0.31)	(0.31)
EDU (Formal education = 1)	0.81	0.81	0.68	0.68	0.80	0.80	0.90	0.90
	(0.39)	(0.39)	(0.47)	(0.47)	(0.40)	(0.40)	(0.30)	(0.30)
Farmer organization (yes = 1)	0.16	0.29	0.23	0.33	0.17	0.35	0.32	0.25
	(0.37)	(0.46)	(0.42)	(0.47)	(0.38)	(0.48)	(0.47)	(0.43)
Pruning (yes = 1)	0.69	0.87	0.59	0.75	0.76	0.88	0.53	0.82
	(0.46)	(0.34)	(0.49)	(0.43)	(0.43)	(0.32)	(0.5)	(0.39)
Improve variety (yes = 1)	0.50	0.72	0.26	0.40	0.53	0.83	0.33	0.71
	(0.50)	(0.45)	(0.44)	(0.49)	(0.50)	(0.37)	(0.47)	(0.46)

[a] Denotes estimates that exclude observations with missing light crop.
[b] Denotes the dependent variable.
Standard deviations are in parenthesis

Figure A1: Villages experiencing CLP-I implementation

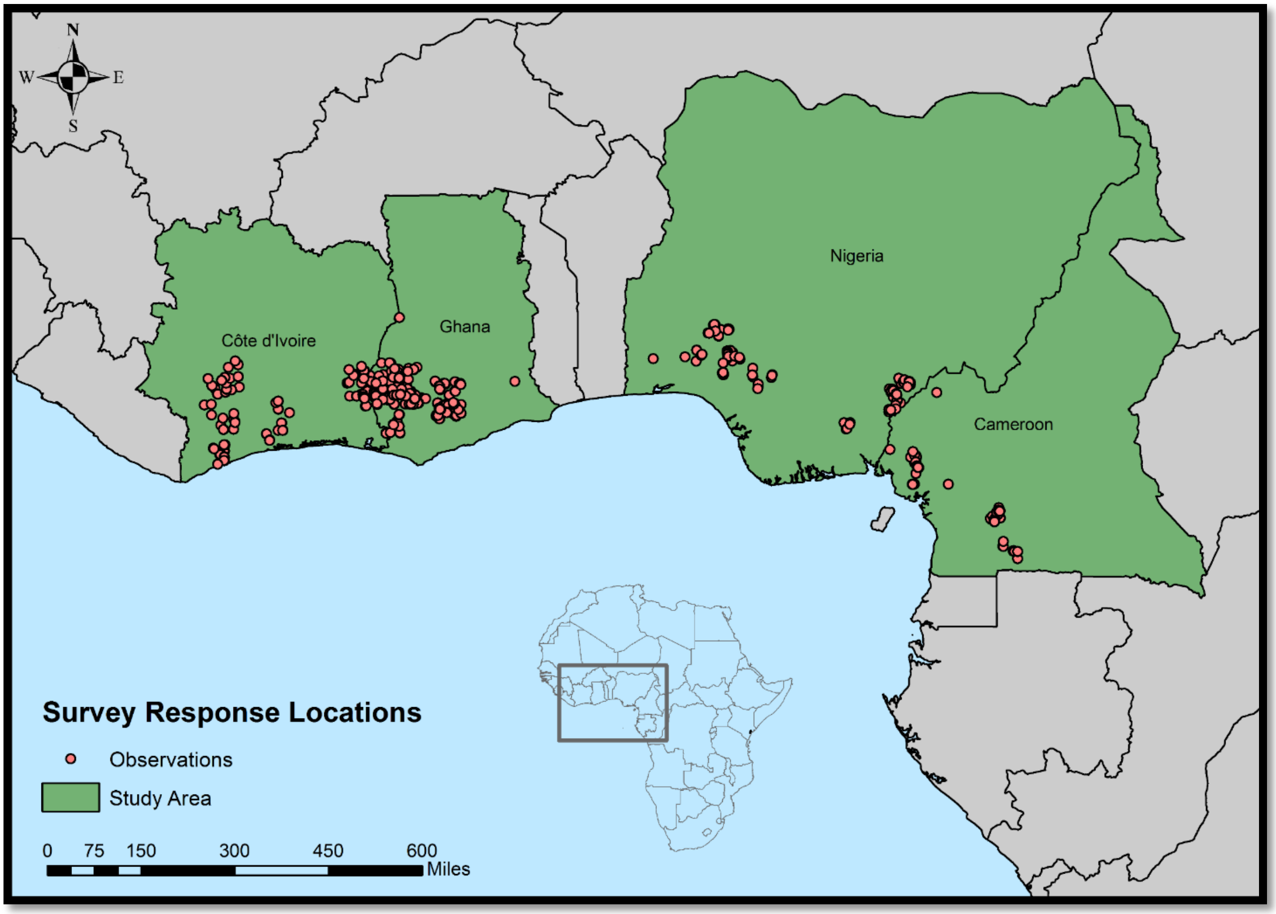
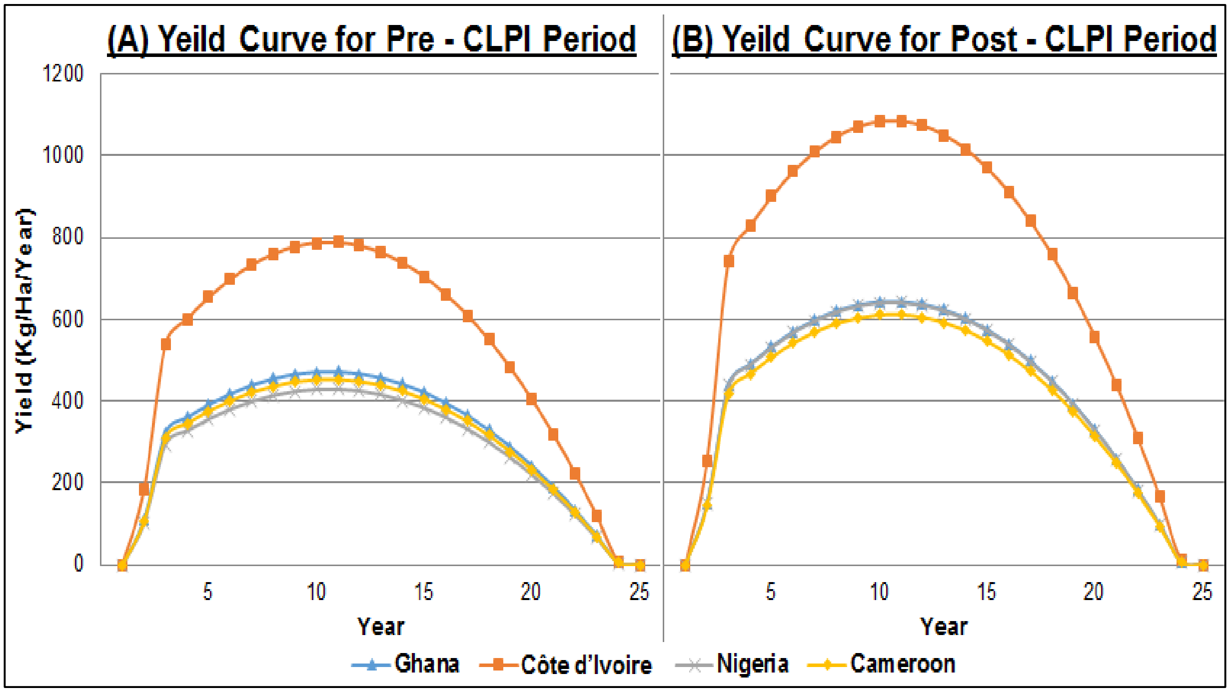


Table A2: Baseline mean differences in selected variables: treatment group mean less control group mean

	GHA	CDI	NGR	CAM
Sample size	350	400	121	152
Yield	47.18	28.63	168.73	58.70
(kg/ha)	(19.19)*	(19.34)	(74.91)*	(20.80)*
Farm size	-0.11	0.54	-0.70	-0.01
(ha)	(0.23)	(0.20)*	(0.35)*	(0.42)
PRECIP1	-3.86	4.76	-	-
(mm)	(7.20)	(5.00)		
PRECIP2	-0.74	14.18	-	-
(mm)	(7.26)	(9.75)		
PRECIP3	-2.14	-5.66	-	-
(mm)	(4.81)	(5.71)		
Inorganic fertilizer	0.01	0.08	0.09	0.03
(yes = 1)	(0.04)	(0.03)*	(0.05)*	(0.04)
Pesticide	0.01	0.17	-0.07	0.08
(yes = 1)	(0.03)	(0.03)*	(0.03)*	(0.05)*
Herbicide	0.03	0.09	0.12	0.14
(yes = 1)	(0.04)	(0.03)*	(0.07)*	(0.07)*
Hired labor	-0.01	0.12	0.03	0.20
(yes = 1)	(0.04)	(0.04)*	(0.04)	(0.08)*
Household labor	0.01	-0.01	0.20	0.04
(yes = 1)	(0.03)	(0.03)	(0.05)*	(0.06)
Farmer gender	0.04	-0.07	-0.03	-0.08
(male = 1)	(0.04)	(0.02)*	(0.05)	(0.05)
EDU	0.05	0.07	0.12	-0.07
(Formal education = 1)	(0.03)	(0.03)*	(0.05)*	(0.05)
Farmer organization	0.05	0.05	0.05	0.11
(yes = 1)	(0.03)	(0.03)	(0.06)	(0.07)
Improve variety	0.01	-0.00	0.04	0.05
(yes = 1)	(0.04)	(0.03)	(0.06)	(0.08)
Pruning	-0.03	0.04	0.11	-0.02
(yes = 1)	(0.03)	(0.03)	(0.05)*	(0.07)

Significance levels: * p<0.10, ** p<0.05, ***p<0.01
Each figure in the table for a given variable is the experimental group mean less the control group mean.
Standard error are in parenthesis

Figure A2. Cocoa yield curves over one production cycle (25 years) in Pre- and Post- CLP-I Periods in Ghana, Côte d'Ivoire, Nigeria and Cameroon



Source: Generated from production systems presented in Afari-Sefa et al. (2010) and Gockowski et al. (2011)

Table A3: Estimated cost of inputs for production and yield multipliers

Country	Yield Multiplier [a]	Wage (US $/Day) [b]	Pesticide (US $/L) [c]	Fungicide (US $/50g) [c]	Fertilizer (US $/50kg) [c]
GHA	1.00	2.22	6.17	1.85	13.52
CDI	1.67	2.59	9.54	2.86	20.91
NGR	0.91	3.88	7.03	2.11	15.41
CAM	0.96	2.00	9.94	2.98	21.79

Note:
[a] Ghana =1 estimated from results from country fixed effects.
[b] Denotes data retrieved from ILO (2012)
[c] Denotes data estimated using Price Level Indexes (PLI) obtained from World Bank (2011)

Chapter III: Potential Spillover Effects of Farmer Field Schools in Sub-Saharan Africa: The Case of Cocoa

A. Abstract

This study utilized a Farm Household Model to analyze direct cocoa market effects and indirect spillover effects of the Cocoa Livelihood Program (CLP). The main findings are that CLP households benefits more than non-CLP households. The spillover effects of CLP in the maize, cassava, and yam markets are minimal while the rice market experiences a modest increase in its price. Sensitivity analysis shows that the cocoa price declines as the CLP participation rate increases; at a CLP participation rate greater than 59%, net gains from the program in Ghana become negative due to a declining cocoa price as supply increases. Also, demand expansion leads to a rises in the cocoa price. Based on these results, the CLP could be expanded from its current rate of 6.25% of cocoa farmers to 59%. However without demand expansion, expanding CLP participation beyond 59%, will lead to welfare lose. Hence, marketing and cocoa demand expansion are equally as important as production expansion to increase rural farm household income. Given the expected increase in world cocoa demand (Taylor, 2013), this is a crucial time to promote Sub-Sahara African cocoa and further establish supply links in this burgeoning market.

B. Introduction

Ghana is the world's second largest cocoa producer, accounting for 24% of total world cocoa exports (ICCO, 2012a).Cocoa production accounts for approximately 55% of total income for rural cocoa producing households and about 38% of total income for urban cocoa producing households (GSS, 2013). As one of the principal agricultural export commodities in the country, cocoa accounted for 3.2% of Ghana's GDP and about 12% of agricultural GDP for the period 2010-2012 (SRID-MOFA, 2013). In 2011 cocoa product exports were valued at US $876 million (SRID-MOFA, 2013). Despite its importance to the Ghanaian economy, the majority of cocoa production is done by small scale household farms on two-to-four hectare plots (WCF, 2009, 2014), which consists of about 17% of all rural households (GSS, 2013, 2014). With low levels of input usage, the average yield for the period 2000-2010 is estimated to be 360 kg/ha which is 22.4% below the world average of 464kg/ha (FAO, 2015). Given the historically low levels of research in cocoa production in Ghana and other Sub-Saharan African countries, farmers have difficulty addressing issues such as yield loss - 30% loss annually - due to pests and diseases, inadequate access to inputs, antiquated farming techniques, limited availability of improved varieties, and limited organizational support (ICI, 2011). Together these have ultimately led to low cocoa yields relative to Asian countries such as Indonesia and Vietnam, low cocoa farm gate prices, and low or even negative returns on cocoa production. Solutions to these challenges are often offered by agricultural extension agencies.

In order to fill the cocoa extension gap, the Cocoa Livelihood Program (CLP), a current World Cocoa Foundation (WCF) development program funded at US $40 million by the Bill and

Melinda Gates Foundation and matching grants was implemented in 2009.[11] The aim of CLP is to double the income of approximately 200,000 smallholder cocoa-growing households in Ghana, Côte d'Ivoire, Nigeria, Cameroon, and Liberia. The objectives of CLP phase one (CLP-I) (from February 2009 to January 2014) were to (1) improve market efficiency and build capacity of farmers and farmer organizations, (2) increase cocoa production and quality at the farm level, and (3) improve competitiveness by increasing farm diversification (Ndiaye et al., 2013). Farmers who participated in CLP-I were provided training in the form of Farmer Field School (FFS) and Farmer Business School (FBS). Subsequently, farmers who were credit worthy and had completed both FFS and FBS were extended credit through an Input Credit Package (ICP) to obtain inputs (fertilizers and agro-chemicals) for production. The ICP provided credit to purchase subsidized inputs at the beginning of the growing season, which was paid back after harvest. For phase two (CLP-II) (February 2014 to January 2019) the focus is scaling up and building upon best practices, lessons learned, and the partnerships developed in CLP-I. In addition CLP-II will is also aimed at improving cocoa yields, but also food crops grown by cocoa farmers such as maize, cassava and yams.

Two recent studies on CLP-I have found that yield gains attributable to CLP-I are statistically significant and substantial. Norton et al. (2013) found that, for a sample of 138 CLP participants in Ghana who were exposed to the full CLP-I package (i.e., FFS, FBS, and ICP), average yield rose by 75%. Building on the work of Norton et al. (2013), Tsiboe et al. (2015) applied the difference-in-differences modelling method to data collected from 700 pre- and post-

[11] World Cocoa Foundation (WCF) was founded in 2000 to promote social and economic development and environmental stewardship in cocoa-growing communities through public-private partnerships (WCF, 2015).

CLP interviews of Ghanaian cocoa farmers. Their results showed yield gains attributable to the full CLP-I package to be 32%. Tsiboe et al. (2015) and Norton et al. (2013) also estimated annual benefits of US $201 and US $61 per beneficiary over 25 years and the benefit-cost ratio of the program to be US $80 and US $18 for every dollar spent on human capital development, respectively.

While assessing the direct impact of developmental programs is valuable, it should be kept in mind that the manner in which agricultural households respond to these programs and the spillover effects into other sectors of the economy is also important when assessing development programs such as CLP. For example, in the case of CLP-I, the yield enhancement could impact the world cocoa price given that Ghana is the second largest producer globally and a major share of Ghana's cocoa is exported. Ghana could very well be a price maker not a price taker given its large share of world production. Also, CLP-I potentially affects household consumption. The impact of increased cocoa yields and income for cocoa producers on the demand and supply response of staple food markets is important to analyze. To address these issues, it is imperative to understand the factors that influence production and consumption (of both cocoa and food staples), demand for production inputs (fertilizer, fungicide, capital, and land), and labor/leisure decisions. Farm Household Models (FHM) are able to capture the aforementioned relationships in a theoretically consistent fashion; as such, their results can be used to illustrate the outcomes of developmental programs beyond their intended direct impacts (Singh et al., 1986).[12] The staple food considered include the top two most consumed cereals (maize and rice) and

[12] See Reid (1934), Becker (1965), Sen (1966), Berry and Soligo (1968) , Barnum and Squire (1979), Singh et al. (1986), Chaianov et. al. (1986), McKay and Taffesse (1994), and Jorgenson and Lau (2000) for a detailed review of the FHM literature

roots/tubers (cassava and yams). Together these for crops provide 42.4% of the total daily food caloric supply in Ghana (FAO, 2015).

One unique factor of the world cocoa market is that, due to changes in consumer preferences toward dark chocolate (which requires more cocoa by volume), the rise of the middle class in many Asian countries, and political and medical (Ebola) turmoil in large production areas (Côte d'Ivoire and Liberia), demand has consistently outpaced supply. The price of cocoa has increased from about 1.54 US $/kg in 2005 to 3.05 US $/kg in 2014 (ICCO, 2015b). Furthermore, the price of cocoa is expected to again double by 2020 if demand continues to outpace supply (Taylor, 2013). The continual outpacing of demand relative to supply has important implications for producer income and consumption patterns.

In this study, a FHM is used to evaluate cocoa market outcome and the spillover effects of CLP-I in of Ghana. Specifically, the objectives of this study are: (1) to formulate and calibrate a FHM for cocoa producers in Ghana; (2) to quantify the effects of CLP-I on equilibrium price, quantities, and welfare in the cocoa export market and domestic food markets for maize, rice, cassava, and yam; and (3) to undertake an ex-ante analysis of CLP Phase II (CLP-II) under different CLP expansion outcomes and demand expansion based on the known results of farmers participating in CLP-I quantified in objective (1).

The primary contribution of this study to the literature is applying the FHM to measure, not only the direct, but also the indirect impact of programs aimed at increasing farmers' income through yield enhancement extension programs in low-income countries. This study also evaluates the probable impacts of the CLP-II program currently being implemented by WCF and demand expansion. While many studies have evaluated the direct impact of development programs for cocoa farmers in Sub-Saharan Africa (Diegert et al., 2014; Gockowski et al., 2010;

Norton et al., 2013; Opoko et al., 2009), none in the available literature have estimated their indirect impacts on external markets.

C. The Farm Household Model (FHM)

For most low-income countries, the agriculture sector accounts for a major share of the income of the rural population. As such, policies implemented to foster growth in this sector are ultimately determined by the response of both farm households and agro-enterprises. However, predicting the impact of such policies is complicated and has spillover effects that are not clear cut. Thus, the impact of any policy that is the catalyst for change in the agriculture sector must be traced through simultaneous changes in both the production and consumption behavior of farm households.

According to Singh et al. (1986) FHMs can be used to examine the impact of policies in three domains. First, FHM's are able to measure the impact of alternative policies on the well-being (e.g., household income or nutritional status) of representative farm households. Secondly, given the interest of low income countries in the macroeconomic performance of the agricultural sector, FHM's provide an appropriate framework that considers the production and consumption response by farm households due to changes in different types of policies including those targeted at agriculture sector and rural communities. Finally, FHM's can assess the spillover effects of policies targeted at farm households (agriculture sector) on other household groups and sectors of the economy. We can therefore use FHM to analyze the impact of CLP-I on the smallholder cocoa-growing households and non-cocoa-growing or non-farm segments of the economy. Also, due to logistical limitations and eligibility criterion, not all cocoa-growing households in Ghana will be reached by the CLP-I program. Since FHM incorporates total and family labor use, it can analyze the effects of CLP-I on labor and the incomes of both cocoa-growing households enrolled or not enrolled in CLP-I, and also the effects of an increase in profits attributable to CLP-I on the demand for maize, rice, cassava, yam, and goods and services not produced by cocoa-growing households.

1. A Farm Household Model for Ghanaian Cocoa Farming Households

While the model developed here is specified around the FHM, it has two key deviations from a standard FHM. First, cocoa is a cash crop that is not consumed as a staple food by farm households. Thus, all production is surplus and sold at the market price, while the labor/leisure decision maintains the connection between production and utility. As such, cocoa producing households use income from cocoa production and other non-farm activities to purchase non-food items and residual demand for staple foods not met by household production of staple foods. A representative cocoa farm household maximizes its utility from the consumption of staple foods C_i (i = 1 for cassava, 2 for yam, 3 for maize, and 4 for rice), a composite good C_5 consisting of all non-staple food and non-food consumption, and leisure C_6, according to the Stone-Geary utility function (Neary, 1997):

$$\max_{C_1^k,\dots,C_6^k}(U^k) = \max_{C_1^k,\dots,C_6^k}\left(\prod_{i=1}^{4}\left(C_i^k - d_i^k\right)^{\alpha_i}\left(C_5^k\right)^{\alpha_5}\left(C_6^k\right)^{\alpha_6}\right), \qquad (1)$$

where d_i is the subsistence level of staple food consumption and satisfies Engel's Law and α_i are their respective consumption shares[13]. The superscript k is a group designation for CLP exposed households (k = 1) and non-CLP households (k = 0). Exposure to CLP (k = 1) is defined as having received the full CLP-I package as defined by Tsiboe et al. (2015).

Cocoa is produced according to the Cobb-Douglas production function:

[13] A household will always consume d_i irrespective of its income or the price, as such as its income increases, the percentage of income used to buy the residual Ci decreases, provided prices do not increase or at least stay the same.

$$S_c^k = z_c^k (l^k)^{\beta_{l0}} \prod_{j=1}^{4} \left(x_j^k\right)^{\beta_j} \quad \left(0 < \beta_{l0} + \sum_{j=1}^{4} \beta_j < 1\right), \qquad (2)$$

where z_0^k is the cocoa productivity parameter, l^k is labor used in cocoa production, x_j^k are non-labor inputs to production (*j* = 1 for fertilizer, 2 for insecticide/pesticide, 3 for other agro-chemicals, and 4 for equipment/capital), and β_j are output elasticities of inputs. The representative cocoa household also produces cassava, yam, and maize for household consumption, according to the to the Cobb-Douglas production function:

$$h_{c_i}^k = z_i^k \left(l_{fi}^k\right)^{\beta_{li}} \left(A_i^k\right)^{\beta_{Ai}} \qquad (\beta_{li} + \beta_{Ai} = 1), \qquad (3)$$

where z_i^k is their respective productivity parameters, l_{fi}^k is the amount of household labor used in their production, A_i^k is the land use, and β_{li} and β_{Ai} are output elasticities of the two inputs. No hired labor is utilized in cassava, yam, and maize production because these food items are for household consumption only. Note that because of weather conditions, cocoa growing households do not produce rice.

Equation *(1)* is maximized subject to the cash income, production, labor use, and total time availability constraints:

$$\sum_{i=1}^{5} P_{c_i} C_i^k = P_c S_c^k + \sum_{i=1}^{3} \left[P_{c_i} h_{c_i}^k\right] + T^k - w l^k - \sum_{j=1}^{4} \left[P_{x_j} x_j^k\right] - \sum_{i=1}^{3} \left[r A_i^k\right] \qquad (4)$$

$$l^k = l_h^k + l_{f0}^k, \qquad (5)$$

$$t^k = C_6^k + l_{f0}^k + \sum_{i=1}^{3} l_{fi}^k, \qquad (6)$$

where *w*, r, P_{x_j}'s, P_{c_i}, P_c, and *T* are the wage rate, rental rate of land, the respective prices for the j^{th} non-labor inputs, the price of i^{th} consumption good, the price of cocoa, and all other non-cocoa income, respectively. Note that because of the perennial nature of cocoa trees, land is assumed to be a fixed factor of cocoa production and dictates the degree of decreasing returns-to-scale in the production function. It should be noted that, unlike the cocoa production function, that of the staple foods exhibit constant returns-to-scale; as such there are zero profits to the household. Equation *(5)* implies that total labor used in cocoa production (l^k) is equal to hired labor (l_h^k) plus family labor (l_{f0}^k). Equation *(6)* equates the farm household's total time availability (t^k) to time spent on cocoa farming (l_{f0}^k), staple food farming (l_{fi}^k), and at leisure (C_6^k).

Substituting equations *(2)*, *(3)*, *(5)*, and *(6)* into *(4)* and simplifying gives the full-income constraint:

$$wC_6^k + \sum_{i=1}^{5} P_{c_i} C_i^k = wt^k + \pi_0^k + \sum_{i=1}^{3} \pi_i^k + T^k, \qquad (7)$$

$$\pi_0^k = P_c z_c^k (l^k)^{\beta_{l0}} \prod_{j=1}^{4} \left(x_j^k\right)^{\beta_j} - wl^k - \sum_{j=1}^{4} P_{x_j} x_j^k, \qquad (8)$$

$$\pi_i^k = P_{c_i} z_i^k \left(l_{fi}^k\right)^{\beta_{li}} \left(A_i^k\right)^{\beta_{Ai}} - wl_{fi}^k - \sum_{i=1}^{3} rA_i^k = 0, \qquad (9)$$

where π_0^k and π_i^k are the profits from cocoa and staple food production, respectively. The left-hand side of Equation *(7)* is total household expenditures on the i^{th} staple food good, the composite good, and purchase of its own time in the form of leisure, i.e., the opportunity cost of leisure. The right-hand side of Equation *(7)* is an extension of Becker (1965)'s concept of full income which consists of total time valued at the market wage rate (Becker, 1965), profit from cocoa and staple food production, and any non-labor, nonfarm income. Note that constant returns-to-scale of the staple food production functions implies that π_i^k is equal to zero.

The Lagrangian for maximizing utility (equation *(1))* subject to the full-income constraint (equation *(7)*) is:

$$\mathcal{L}^k = \max_{C_i^k, l^k, x_j^k, l_{fi}^k, A_i^k} U^k + \lambda^k \left[wt^k + \pi_0^k + \sum_{i=1}^{3} \pi_i^k + T^k - \left(wC_6^k + \sum_{i=1}^{5} P_{c_i} C_i^k\right)\right]. \qquad (10)$$

Taking the partial derivatives ($\mathcal{L}_n^k = \frac{\partial \mathcal{L}^k}{\partial n}$) of $\mathcal{L}^k$ with respect to the *n^th^* argument (*n* = $C_i^k, l^k, x_i^k, l_{fi}^k, A_i^k, \lambda^k$) and setting them equal to zero—where consumption choices C_i^k are expressed in term of ratios to eliminate λ^k—yields the first-order conditions:

$$\mathcal{L}_{C_i^k}^k / \mathcal{L}_{C_5^k}^k = \alpha_i C_5^k \left(\alpha_5 \left(C_i^k - d_i^k\right)\right)^{-1} - P_{c_i}\left(P_{c_5}\right)^{-1} = 0, \quad (i = 1,\dots, 4), \tag{11}$$

$$\mathcal{L}_{C_6^k}^k / \mathcal{L}_{C_5^k}^k = \alpha_6 C_5^k \left(\alpha_c C_6^k\right)^{-1} - w p_c{}^{-1} = 0, \tag{12}$$

$$\mathcal{L}_{l^k}^k = \beta_{l0} P_c z_0^k \,(l^k)^{\beta_{l0}-1} \prod_{j=1}^4 \left(x_j^k\right)^{\beta_j} - w = 0, \tag{13}$$

$$\mathcal{L}_{x_j^k}^k = \beta_j P_c z_0^k (l^k)^{\beta_{l0}} \left(x_j^k\right)^{\beta_j - 1} \prod_i \left(x_i^k\right)^{\beta_i} - P_{x_j} = 0 \quad (j = 1,\dots, 4), (j \neq i), \tag{14}$$

$$\mathcal{L}_{l_{fi}^k}^k = \beta_{li} P_{C_i} z_i^k \left(l_{fi}^k\right)^{\beta_{li}-1} \left(A_i^k\right)^{\beta_{Ai}} - w = 0 \qquad (i = 1, 2, 3), \tag{15}$$

$$\mathcal{L}_{A_i^k}^k = \beta_{Ai} P_{C_i} z_i^k \left(l_{fi}^k\right)^{\beta_{li}} \left(A_i^k\right)^{\beta_{Ai}-1} - r = 0 \qquad (i = 1, 2, 3), \tag{16}$$

$$\mathcal{L}_{\lambda^k}^k = w t^k + \pi_0^k + \textstyle\sum_{i=1}^3 \pi_i^k + T^k - \left(w C_6^k + \sum_{i=1}^5 P_{c_i} C_i^k\right) = 0. \tag{17}$$

Even though the labor and leisure decisions are part of the same problem and connected through equations *(2)*, *(3)*, and *(5)*, production and consumption decision can be solved sequentially. Optimal production decisions are made by solving equations *(13)*-*(16)* simultaneously, a standard condition consistent with profit-maximizing behavior. A critical attribute of these equations is that they contain only endogenous variables that are relevant to production and none of the endogenous consumption variables (C_i), particularly for leisure. As a result, production choices are independent of consumption choices, provided second-order conditions are met. By substituting the input demand functions into the profit equation yields the maximized value of cocoa profits (π_0^{k*}) and that of the staple foods (noting that because of the constant returns-to-scale of the staple food production functions, the maximum value of π_i^k is equal to zero), which fully characterized income in equation *(7)*:

$$wC_6^k + \sum_{i=1}^{5} P_{c_i} C_i^k = Y^{k*}, \quad (18)$$

$$Y^{k*} = wt^k + \pi_0^{k*} + T^k. \quad (19)$$

Having first maximized profits from cocoa and staple food production, the household then maximizes utility subject to full income given by equation *(18)*. Equations *(13)*-*(16)*, and *(18)* can then be solved simultaneously to obtain the demand function for the consumptions goods (C_i) in terms of cocoa price (P_c), staple food prices (P_{c_i}), the utility parameters (α_i, d_i), and optimal income (Y^{k*}). The derived Marshallian demand function for the i^{th} staple foods are:

$$C_i^{k*} = \alpha_i \Omega_0^k \left(P_{c_i} \sum_{i=1}^{6} \alpha_i\right)^{-1} + \Omega_i^k \quad (20)$$

$$\Omega_0^k = Y^{k*} - \sum_j P_{c_j} d_j^k \qquad (j = 1,\ldots, 4) \quad (j \neq i), \quad (21)$$

$$\Omega_i^k = \frac{d_i^k\left(\sum_j \alpha_j\right)}{\sum_{i=1}^{6} \alpha_i} \qquad (j = 1,\ldots, 4) \quad (j \neq i), \quad (22)$$

where Ω_0^k and Ω_i^k are exogenous constant that are a function of food prices (P_{c_i}), subsistence level of staple food consumption (d_i), consumption shares (α_i), and optimal income (Y^{k*}) from equation *(19)*.

For the composite good (C_5) and leisure (C_6) their Marshallian demand function are:

$$C_5^{k*} = \alpha_5 \Omega_0^k \left(P_{c_5} \sum_{i=1}^{6} \alpha_i\right)^{-1}, \quad (23)$$

$$C_6^{k*} = \alpha_6 \Omega_0^k (w \sum_{i=1}^{6} \alpha_i)^{-1}. \quad (25)$$

To maintain focus on the market outcomes of CLP implementation on cocoa and the spillover effects on other agricultural markets, we define the market clearing conditions for the staple food and cocoa. Given that Ghana is a net importer of production inputs (fertilizer, pesticide, fungicide, and insecticide), and the low input use in the cocoa sector, the input prices are exogenous and equal to their domestic price. [14] The price of the composite good is also taken as given. The market clearing conditions for the staple food items in Ghana are:

$$D_{c_i} P_{c_i}^{\eta_i} + \sum_{k=0}^{1} C_i^{k*} = S_{c_i} P_{c_i}^{\emptyset_i} + h_{c_i}^{k*} \qquad (i = 1,\ldots, 4)\ \forall i, \qquad (26)$$

$$h_{c_i}^{k*} = z_i^k P_{c_i} \left(\frac{\beta_{li}}{w}\right)^{\beta_{li}} \left(\frac{\beta_{Ai}}{r}\right)^{\beta_{Ai}} \qquad (i = 1,\ldots, 4)\ \forall i, \qquad (27)$$

where D_{c_i} is the scale parameter for the residual demand from non-cocoa growing households in Ghana (ROG), and η_i is the demand elasticity for the *i*th staple food, S_{c_i} is the scale parameter of the residual supply of the *i*th staple food from ROG, $\emptyset_i$ is the supply elasticity for the *i*th staple food, and $h_{c_i}^{k*}$ is the optimal household production of the *i*th staple food. Again, the superscript *k* is the group designation; CLP exposed households (*k* = 1) and non-CLP households (*k* = 0). The left-hand side of equation *(8.0)* is the total Ghanaian demand of the *i*th staple food, while the right -hand side the total Ghanaian supply.

The world cocoa price is assumed to be endogenous for Ghanaian cocoa farmers for two reasons. First, given that Ghana is the world's second largest cocoa exporter and accounts for 24% of total world exports (ICCO, 2012a), any shock to Ghanaian cocoa production would influence the world price. Secondly, as the sole exporter and regulator of Ghanaian cocoa, the Ghana Cocoa Board (COCOBOD) sets the farm gate price of cocoa (P_c) in Ghana as a share of world cocoa price, which is equivalent to:

$$P_c = \tau(P_c^w), \qquad (28)$$

[14] Aside from the low input use by cocoa farmers, it is estimated that 86% of fertilizer is imported and only 13% of fertilizer is used in cocoa (SRID-MOFA, 2013)

where P_c^w is the world price of cocoa and τ is imposed by the marketing board.[15] Thus world market fluctuations to be transmitted to farmers. For simplicity, we assume that Ghanaian farmers face a residual demand function equal to Ghana's share of the world market. The market clearing condition is given by:

$$\sum_{k=0}^{1} S_c^k = D_c P_c^{\eta_c} I^{\,\rho_c} \qquad \forall i, \tag{29}$$

where S_c^{k*} is the profit maximizing cocoa supply function represented as:

$$S_c^{k*} = \theta^k \left((P_c)^{\left(\beta_l + \sum_{j=1}^{4} \beta_j\right)\left(1 - \beta_l + \sum_{j=1}^{4} \beta_j\right)^{-1}} \right) \tag{30}$$

$$\theta^k = \left(z^k \left(\frac{\beta_l}{w}\right)^{\beta_l} \prod_{j=1}^{4} \left(\frac{\beta_j}{P_{x_j}}\right)^{\beta_j} \right)^{\left(1 - \beta_l + \sum_{j=1}^{4} \beta_j\right)^{-1}}, \tag{31}$$

where θ^k is an exogenous constant that is a function of input prices (w, P_{x_j}) and the productivity parameters (z_0^k), D_c is the scale parameter for the residual world demand for Ghanaian cocoa, and η_c and ρ_c are the demand and income elasticities for Ghanaian cocoa on the world market.

The first order conditions equations given by *(11)-(17)* and market clearing conditions given by equations *(26)* and *(29)* define a system of 39 equations in 39 variables C_i^k, l^k, l_{fi}^k, A_i^k, x_i^k, P_{C_i}, P_c; 17 each for households with full-CLP training (*k* = 1) and non-CLP households (*k* = 0), 4 for the staple food markets, and 1 for the cocoa market.

[15] The cocoa sector in Ghana is partly liberalized, allowing private licensed buying companies (LBCs) to buy, sell, and transport cocoa. LBCs sell to COCOBOD on commission and local processing companies, however if they are able to meet a minimum quantity of beans they become eligible to export. The share $(1 - \tau)$ of the world cocoa price not given to farmers is used to finance extension activities of COCOBOD, provide rural development for cocoa growing communities, and scholarship schemes for children of cocoa farmers.

2. The Impact of CLP on Ghanaian Cocoa Farming Households

Next we identify the channels by which full CLP-I treatment through FFS and FBS training and the subsequent ICP influence production. The FFS and FBS training both influence yield through the productivity parameter (z_c^k) in the production function (equation *(2)*) while ICP influences production though subsidized input costs.

Because input prices are exogenous to the farmers, θ^k remains constant for households that do not participate in CLP-I training (*k* = 0). However, for the households exposed to CLP training (*k* = 1), θ^k will change because they experience a productivity shock and receive fertilizer at a subsidized rate. Thus, the change in the productivity parameter and the input subsidy for the CLP exposed households are:

$$z_c^{clp} = (1 + \sigma) z_c^1, \tag{32}$$

$$P_{x_1}^{clp} = (1 - \vartheta) P_{x_1}, \tag{33}$$

where and z_c^{clp} and $P_{x_1}^{clp}$ are the new productivity parameter and the subsidized fertilizer price. The parameter σ is the productivity shock from FFS and FBS training, and the parameter ϑ represents the discount farmers get from the Input Credit Program from CLP-I.

D. Welfare Analysis

1. Welfare changes in the world market for Ghanaian cocoa:

Welfare changes for the Ghanaian cocoa market consists of changes in producer and consumer surplus for Ghanaian cocoa. For the producer surplus, because of the implementation of CLP-I, there is not only a movement along the supply function as prices adjust to market forces, but there is also a supply shift for the CLP-I exposed households (*k* = 1) due to the fertilizer subsidy and the productivity shock (θ^k). Thus, the change in producer surplus (ΔPS_c) is calculated as the difference in total producer surplus before and after CLP-I is implemented:

$$\Delta PS_c = \sum_{k=0}^{1} \left[\int_0^{P_c^a} S_c^k \, dP_c - \int_0^{P_c^b} S_c^k \, dP_c \right], \tag{34}$$

$$\Delta PS_c = \left(1 - \beta_l + \sum_{j=1}^{4} \beta_j\right) \left[(\theta^k)^a \left((P_c)^{\left(1-\beta_l+\sum_{j=1}^{4}\beta_j\right)^{-1}} \right) - (\theta^k)^b \left((P_c^b)^{\left(1-\beta_l+\sum_{j=1}^{4}\beta_j\right)^{-1}} \right) \right]. \tag{35}$$

As discussed in the introduction, global cocoa demand has consistently outpaced global supply. As a result, the residual demand for Ghanaian cocoa shifts due to increases in D_c which reflects changes in consumer preferences toward dark chocolate (which requires more cocoa by volume) and the rise of the middle class in many Asian countries and I which represents income effects of chocolate consumers. Because of the shift in the demand curve, the change in consumer surplus (ΔCS_c) for cocoa consumption is represented as the difference in total consumer surplus before and after CLP-I is implemented:

$$\Delta CS_c = \int_{P_c^a}^{\infty} D_c^a P_c^{\eta} (I^a)^{\rho} \, dP_c - \int_{P_c^b}^{\infty} D_c^b P_c^{\eta} (I^b)^{\rho_c} \, dP_c, \tag{36}$$

$$\Delta CS_c = \left(\frac{D_c^a (I^a)^{\rho_c} - D_c^b (I^b)^{\rho_c}}{\eta_c + 1} \right) (\infty)^{-\eta_c + 1} - \left(\frac{D_c^a (I^a)^{\rho_c} - D_c^b (I^b)^{\rho_c}}{\eta_c + 1} \right) (P_c^b)^{\eta_c + 1}. \tag{37}$$

Because demand for agricultural goods are general inelastic ($\eta < 1$), including cocoa, the first term on the right-hand side of equation (*37*) is infinite, implying that ΔCS_c is infinite. Because an infinite price and CS are unrealistic, a maximum cocoa price P_c^{max} is imposed to compute a finite value for ΔCS_c. As such, the change in consumer surplus (ΔCS_c^*) for cocoa consumption is now represented as:

$$\Delta CS_c^* = \left(\frac{D_c^a (I^a)^{\rho_c} - D_c^b (I^b)^{\rho_c}}{\eta_c + 1} \right) (P_c^{max})^{\eta_c + 1} - \left(\frac{D_c^a (I^a)^{\rho_c} - D_c^b (I^b)^{\rho_c}}{\eta_c + 1} \right) (P_c^b)^{\eta_c + 1}, \tag{38}$$

In order to reflect the real world, P_c^{max} is assumed to be the highest cocoa price of 5.265 US $/kg for the period 1981-2010 (ICCO, 2012b).

2. Welfare changes in staple food market for Ghanaian:

Similar to the cocoa food market, welfare in the staple food market for Ghana is comprised of changes in producer and consumer surplus. Representing the pre- and post-CLP-I price for the i^{th} staple food by $P_{c_i}^b$ and $P_{c_i}^a$, respectively, and using the demand function given by equation *(27)*, the change in producer surplus ($\Delta PS_{c_i}^k$) for cocoa farmers is given by:

$$\Delta PS_{c_i}^k = \int_{P_{C_i}^a}^{P_{C_i}^b} h_{c_i}^{k*} dP_{C_i} = z_i^k \left(\frac{\beta_{li}}{w}\right)^{\beta_{li}} \left(\frac{\beta_{Ai}}{r}\right)^{\beta_{Ai}} \left(\frac{\left(P_{C_i}^a\right)^2 - \left(P_{C_i}^b\right)^2}{2}\right). \qquad (39)$$

The change in producer surplus for ROG ($\Delta PS_{D_{C_i}}$), using the supply function (the first term on the right-hand side of equation *(26)*) for non-cocoa farmers, is:

$$\Delta PS_{D_{C_i}} = \int_{P_{C_i}^a}^{P_{C_i}^b} S_{C_i} P_{C_i}^{\emptyset_i} dP_{C_i} = \frac{S_{C_i}}{1+\emptyset_i}\left(\left(P_{C_i}^a\right)^{1+\emptyset_i} - \left(P_{C_i}^b\right)^{1+\emptyset_i}\right). \qquad (40)$$

The total change in producer surplus (ΔPS_{C_i}) for the i^{th} staple food in Ghana following CLP-I implementation is the aggregation of cocoa farmer and non-cocoa farmers:

$$\Delta PS_{C_i} = \Delta PS_{D_{C_i}} + \sum_{k=0}^{1} \Delta PS_{C_i}^k. \qquad (41)$$

For consumer surplus recall that the constant (Ω_0^k) in equation *(20)* is a function of subsistence level of staple food consumption (d_i), consumption shares (α_i), and optimal income (Y^{k*}); any change in theses parameters will affect consumer surplus for the i^{th} staple food for cocoa households. Because CLP-I exposed households (k = 1) experience a productivity shock and receive fertilizer at a subsidized rate, optimal income (Y^{1*}) increases and their demand function will shift to the right. Thus using the demand function given by equation *(20)*, the change in consumer surplus ($\Delta CS_{c_i}^k$) for cocoa farmers is given by the difference in pre- and post-CLP-I total consumer surplus:

$$\Delta CS_{c_i}^{k} = \sum_{k=0}^{1}\left[\int_{P_{c_i}^{a}}^{\infty} C_i^{k*}\, dP_{c_i} - \int_{P_{c_i}^{b}}^{\infty} C_i^{k*}\, dP_{c_i}\right], \tag{42}$$

$$\Delta CS_{c_i}^{k} = \alpha_i[\textstyle\sum_{i=1}^{6}\alpha_i]^{-1}\left[ln|\infty|\left(\Omega_0^{ka} - \Omega_0^{kb}\right) - \Omega_i^{k}\left(P_{c_i}^{a} + P_{c_i}^{b}\right) + \Omega_0^{kb}\, ln\left|P_{c_i}^{b}\right| - \Omega_0^{ka}\, ln\left|P_{c_i}^{a}\right|\right] \tag{43}$$

Again, the superscript *b* and *a* present the baseline scenario (pre-CLP-I period) and alternate scenario (post-CLP-I period). Because of the infinite price in the term, $\ln|\infty|\left(\Omega_0^{ka} - \Omega_0^{kb}\right)$, the calculated $\Delta CS_{c_i}^{k}$ by equation *(43)* is unrealistic, as such a maximum price ($P_{c_i}^{max}$) for the *i*th staple food is imposed to compute a finite values for $\Delta CS_{c_i}^{k}$. Hence the change in consumer surplus ($\Delta CS_{c_i}^{k}$) for *k*th cocoa farm household is now represented as:

$$\Delta CS_{c_i}^{k} = \alpha_i[\textstyle\sum_{i=1}^{6}\alpha_i]^{-1} \times$$

$$\left[ln\left|P_{c_i}^{max}\right|\left(\Omega_0^{ka} - \Omega_0^{kb}\right) - \Omega_i^{k}\left(P_{c_i}^{a} + P_{c_i}^{b}\right) + \Omega_0^{kb}\, ln\left|P_{c_i}^{b}\right| - \Omega_0^{ka}\, ln\left|P_{c_i}^{a}\right|\right]. \tag{44}$$

In order to reflect the real world, $P_{c_i}^{max}$ is assumed to be the highest *i*th staple food price for the period 2000-2010 reported by FAO (2015).

The change in consumer surplus for ROG ($\Delta CS_{D_{C_i}}$), using the demand function for non-cocoa farmers (first term on the left-hand side of equation *(26)*), is:

$$\Delta CS_{D_{C_i}} = \int_{P_{C_i}^{a}}^{P_{C_i}^{b}} D_{C_i}\, P_{C_i}^{-\eta_i}\, dP_{C_i} = \frac{D_{C_i}}{\eta_i+1}\left(\left(P_{C_i}^{a}\right)^{\eta_i+1} - \left(P_{C_i}^{b}\right)^{\eta_i+1}\right). \tag{45}$$

The total change in consumer surplus (ΔCS_{C_i}) for the *i*th staple food in Ghana following CLP-I implementation is the aggregation of cocoa farmer and non-cocoa farmers:

$$\Delta CS_{C_i} = \Delta CS_{D_{C_i}} + \textstyle\sum_{k=0}^{1}\Delta CS_{C_i}^{k}. \tag{46}$$

Given the total cost of CLP-I implementation in Ghana ($CLP_{Total\ cost}$) and the changes in consumer and producer surpluses above, the overall welfare measure associated with CLP-I (CLP_{welfare}) is

$$CLP_{welfare} = \Delta PS_c + \Delta CS_c^{*} + \textstyle\sum_i^{4}\left[\Delta CS_{C_i} + \Delta PS_{C_i}\right] - CLP_{Total\ cost}. \tag{47}$$

E. Quantitative Analysis

1. Data

This study uses two sources of micro-level data and two sources of macro-level data to calibrate the model presented in the previous section. The first micro-level data source is the Ghana Living Standards Survey (GLSS) which was based on a nationally representative sample of households. [16] The first GLSS (GLSS1) was conducted in 1987 and the two most recent surveys — GLSS5 and GLSS6 — used in this study were administered in 2005/2006 and 2012/2013, respectively.[17] The GLSS survey provides data on the number of cocoa farming households, the value of production inputs per hectare, annual household budget structure, and time use. The second micro-level dataset is the Ghana Cocoa Farmers Surveys (GCFS) (Zeitlin, 2015). The first round was conducted in 2002 (GCFS1), with follow-up surveys conducted in 2004 (GCFS2) and 2006 (GCFS3), making a 3-year panel.[18] The GLSS survey provides data on quantities of inputs used in cocoa production on a per hectare basis.

Table 1 provides a detailed summary of the relevant data used from GLSS and GCFS. On average, 12.6% of all households in Ghana grow cocoa (GLSS5 and GLSS6), with an average farm size of 5.7 ha and average yield of 310.6 kg/ha (GLSS5, GLSS6, GCFS1, and GCFS3). In terms of the value of inputs used in cocoa production, the GLSS5 and GLSS6 datasets indicate

[16] The Living Standards Measurement Study (LSMS) which includes countries such as Ghana (Ghana Living Standards Survey) is a research project that was initiated in 1980 by the Policy Research Division of the World Bank. The survey focuses on the household as a key socio-economic unit and provides valuable insights into living conditions in Ghana.

[17] For more on sampling and access policy see GSS (2013, 2014).

[18] For more on sampling and data collection see CSAE and COCOBOD (2006).

that the input with the highest relative value is labor (25.8%), followed by land (19.3%), fertilizer (18.6%), equipment/other (16.4%), herbicide (10.8%), and then pesticide (9.1%). The GCFS2 and GCFS3 datasets indicate that, on average, farmers' use 85.0 man-hours/ha of labor annually, about 55.3% of which comes from the household and neighbor exchange labor. The GCFS2 and GCFS3 datasets also reveal that annual fertilizer, pesticide, fungicide, and equipment/other input usage are, on average, 32.7 kg/ha and 1.8 liter/ha, 0.5 liter/ha, and 0.6 unit/ha, respectively. Based on the GLSS5 and GLSS6 datasets, annual expenditure per household member is estimated at US $933.3, where 6.9% is spent on cassava, 3.9% on rice, 3.3% on maize, and 1.8% on yam, and the remainder is spent on other food and non-food consumption (housing, education, healthcare, etc.). The GLSS5 and GLSS6 datasets show that cocoa farm households spend an average 19.2% of their available time on the farm, 4.4% on non-farm work, 9.2% on housekeeping, and the remaining 67.3% on leisure and sleeping.

Data on annual cocoa production, the national food balance sheet, and food price estimates are retrieved from FAO (2015), and world cocoa price data come from ICCO (2015). A summary of the relevant macro data is presented in Table 3. Approximately 9.12% of the 759,805 households growing cocoa have been exposed to at least one of the CLP-I packages as of August, 2013. The average total area harvested for cocoa for the period 2000-2010 is 1.6 million ha.

Table 1: Micro Data Summaries by Data Sources

Variable	Data source				
	GLSS5	GLSS6	GCFS1	GCFS2	GCFS3
Survey year	2005/06	2012/13	2001/02	2003/04	2005/06
Sample size for estimates in the table	765	521	480	445	491
Cocoa population in Sample (φ) (ratio)	0.131	0.120	-	-	-
Average household size ($HHsize$) (count)	4.310	4.349	7.634	6.572	5.805
Avg. cocoa yield ($\bar{Q}$) (kg/ha)	282.818	428.967	235.911	262.204	268.275
Land rental rate (*US $/ha/year)*	-	-	-	67.018	235.193
Production inputs					
Value (US $/ha)					
Land (V_A)	16.824	10.879	-	-	-
Total labor (V_l)	14.702	26.612	-	160.052	75.363
Fertilizer (V_1)	11.921	17.142	-	24.552	15.409
Pesticide (V_2)	5.960	8.079	-	24.191	23.084
Herbicide (V_3)	2.960	15.914	-	-	-
Fungicide (V_3)	-	-	-	16.979	16.619
Equipment/others (V_4)	9.607	16.522	-	38.072	136.840
Quantity					
Land (ha)	4.854	1.954	6.258	7.508	7.204
Hired labor ($\bar{l}_h$) (man-hours/ha)	-	-	24.559	43.018	32.960
Household labor ($\bar{l}_{f0}$) (man-hours/ha)	-	-	20.822	37.851	50.146
Exchange labor ($\bar{l}_{f0}$) (man-hours/ha)	-	-	4.639	4.774	1.152
Fertilizer ($\overline{x_1}$) (kg/ha)	-	-	3.040	37.476	27.840
Pesticide ($\overline{x_2}$) (liter/ha)	-	-	2.803	1.848	1.708
Fungicide ($\overline{x_3}$) (liter/ha)	-	-	-	0.326	0.725
Equipment/others ($\overline{x_4}$) (unit/ha)	-	-	121.603	0.568	0.582

Exchange rate used for monetary conversion is 1.431 GHC/US $ estimated as the end of 2010 value retrieved from IMF (2014)
All monetary values are in 2010 terms

Table 1: Micro Data Summaries by Data Sources (Cont.)

Variable	Data source				
	GLSS5	GLSS6	GCFS1	GCFS2	GCFS3
Expenditure share (ratio)					
Cassava (δ_1)	0.014	0.022	-	-	-
Yam (δ_2)	0.010	0.011	-	-	-
Maize (δ_3)	0.021	0.019	-	-	-
Rice (δ_4)	0.054	0.057	-	-	-
Time use distribution (ratio)					
Farm work (HR_{FM})	0.202	0.181	-	-	-
Non-farm work	0.034	0.054	-	-	-
Housekeeping	0.121	0.062	-	-	-
Leisure/sleep (HR_l)	0.643	0.702	-	-	-
Share of food consumption produced (ratio)					
Cassava (Φ_{c_1})	0.235	0.402	-	-	-
Yam (Φ_{c_2})	0.531	0.705	-	-	-
Maize (Φ_{c_3})	0.575	0.637	-	-	-
Rice (Φ_{c_4})	0.988	0.993	-	-	-

Exchange rate used for monetary conversion is 1.431 GHC/US $ estimated as the end of 2010 value retrieved from IMF (2014)
All monetary values are in 2010 terms

Average total domestic supply for maize, rice, cassava, and yam for the same period are 88,000 Mt, 46,000 Mt, 2,000,000 Mt, and 530,000 Mt, respectively. Domestic producer prices for these food staples for the same period are 0.34 US $/kg, 0.63 US $/kg, 0.14 US $/kg, and 0.34 US $/kg for maize, rice, cassava and yam, respectively. The average world cocoa price and Ghanaian farm gate price set by COCOBOD for the period 2005-2010 are 3.06 US $/kg and 2.17 US $/kg, respectively.

Table 2: Macro data summaries by data sources

Variable	Value
Population (count)	
Ghana (POP_{GH})	21,170,200
Ghana Households	4,158,536
Farming households	
Cocoa	469,275
Cassava	1,620,905
Yam	969,862
Maize	1,845,898
Rice	370,999
CLP exposure	
CLP-I participants	69,270
Full CLP-I Package recipients	29,338
Cocoa production	
Land (ha)	1,611,550
Yield (kg/ha)	360
Exports (tonnes)	4,250,00
Total domestic demand (Mt) ($\overline{Q_{C_i}}$)	
Maize	1,270,000
Rice	541,000
Cassava	9,970,000
Yam	4,140,000
Subsistence consumption (Mt) ($\overline{d_i}$)	
Maize	88,400
Rice	45,500
Cassava	2,390,000
Yam	530,000
Price (US $/kg) ($\overline{P_{C_i}}, P_c$)	
Maize	0.341
Rice	0.631
Cassava	0.144
Yam	0.343
Cocoa (world)	3.059
Cocoa (Ghana)	2.170

Estimates shown are averages for the period 2000/10.
Exchange rate used for monetary conversion is 1.431 GHC/US $ estimated as the end of 2010 value retrieved from IMF (2014)

2. Calibration

The parameters in the model are calibrated to match the data averaged over the period 2000-2010, before CLP-I was implemented. The calibrated parameters are presented in Table 4. The study first calibrates the production shares and productivity parameters ($\beta_l, \beta_j,$ and z) for cocoa and household staple food production, then subsistence consumption, consumption shares, total available time, non-labor income parameters ($d_i, \alpha_i, \bar{t},$ and T), the supply and demand function parameters for staple food items (S_{C_i},$\emptyset_i$, η_i, and D_{C_i}), and supply function parameters for Ghanaian cocoa (η_c, ρ_c, I, and D_c).

Using average values of input use based on the micro-level datasets GLSS5 and GLSS6, the share parameters for cocoa production are:

$$V_0 = V_A + V_l + \sum_{j=1}^{4} V_j, \qquad (48)$$

where V_0 is the total value of inputs to cocoa production per hectare and V_l, V_1, V_2, V_3, V_4, and V_A represent the value per hectare of labor, fertilizer, insecticide/pesticide, agro-chemicals (recorded as herbicide in the two datasets), equipment/capital, and land, respectively. With the value of production for the i^{th} input, the production share parameters are:

$$\beta_{l0} = V_l(V_0)^{-1} \qquad \beta_j = V_j(V_0)^{-1} \qquad (j = 1,\ldots, 4). \qquad (49)$$

The productivity parameter (z^k) in the production function, equation *(2)*, is calibrated as the residual:

$$z_0^k = \omega^k \bar{Q} \left(\left(\omega^k (\bar{l}_{fo} + \bar{l}_h) \right)^{\beta_{l0}} \prod_{j=1}^{4} \left(\omega^k \bar{x}_j \right)^{\beta_j} \right)^{-1}, \qquad (50)$$

where cocoa production ($\bar{Q}$) is the average for all four datasets (GLSS5, GLSS6, GCFS2, and GCFS3), variables $\bar{l}_{fo},\ \bar{l}_h,\ \bar{x}_1,\ \bar{x}_2,\ \bar{x}_3$, and $\bar{x}_4$, represent the quantities of household labor, hired labor, fertilizer, insecticide/pesticide, agro-chemicals (recorded as fungicide in the two datasets), equipment/capital, and land used in production (values are taken as averages recorded based on GCFS2 and GCFS3 datasets), and ω^k is the proportion of cocoa households that have been exposed to CLP (*k* = 1) or not exposed to CLP (*k* = 0).

Given the annual average cocoa farm gate price ($\bar{P}_c$) in Table 2, and the calibrated parameters of the cocoa production function, the average implied wage rate ($\bar{w}$) and price of the j^{th} non-labor inputs ($\bar{P}_{x_j}$) to cocoa production are then calibrated using the equations *(13)* and *(14)* as:

$$\bar{w} = \beta_{l0}\bar{P}_c z_0^k \, (l^k)^{\,\beta_{l0}-1} \prod_{j=1}^{4}\left(x_j^k\right)^{\beta_j} \ , \qquad (51)$$

$$\bar{P}_{x_j} = \beta_j \bar{P}_c z_0^k (l^k)^{\,\beta_{l0}}\left(x_j^k\right)^{\beta_j-1}\prod_i\left(x_i^k\right)^{\beta_i} \quad (j = 1,\ldots,4) \qquad , (j \neq i). \qquad (52)$$

Using the percentage (φ) of the non-cocoa growing Ghanaian population and the annual average total domestic consumption quantity ($\overline{Q_{C_i}}$) for the i^{th} staple food, the quantity consumed by k^{th} cocoa growing household is calculated as:

$$\bar{C}_i^k = \omega^k(1-\varphi)\bar{Q}_{C_i}, \qquad (i = 1,\ldots, 4). \qquad (53)$$

Given $\bar{C}_i^k$, the amount of the i^{th} staple food produced by the household is calculated as;

$$\bar{h}_{c_i}^k = \left(1-\Phi_{c_i}^k\right)\bar{C}_i^k \qquad (i = 1,\ldots, 3), \qquad (54)$$

where $\Phi_{c_i}^k$ is the percentage of the i^{th} staple food purchased from the market as shown on Table 1. The average quantity of household labor ($\bar{l}_{fi}^k$) used in household production of the i^{th} staple food is:

$$\bar{l}_{fi}^k = \bar{\bar{t}}^k\left(HR_{FM}\frac{\bar{P}_{c_i}\bar{h}_{c_i}}{\bar{P}_c\bar{Q}+\sum_i^3\bar{P}_{c_i}\bar{h}_{c_i}}\right), \qquad (i = 1,\ldots, 3), \qquad (55)$$

where

$$\bar{t}^k = \omega^k\bar{l}_{fo}\left(HR_{FM}\frac{\bar{P}_c\bar{Q}}{\bar{P}_c\bar{Q}+\sum_i^3\bar{P}_{c_i}\bar{h}_{c_i}}\right)^{-1}, \quad (i = 1,\ldots, 3), \qquad (56)$$

The parameter $\bar{t}^k$ is the total time available to household k, HR_{FM} is the average ratio of total household time spent on the farming, taken as the average for the GLSS5 and GLSS6 datasets, and $\bar{P}_{C_i}$ is the annual average price for the *i*th staple food. With the total amount of family labor used in the household production of the *i*th staple food calibrated and the wage ($\overline{w}$) rate calculated from equation *(51)*, the share parameter for family labor (β_{li}) and land (β_{Ai}) in the production of the *i*th staple food is calibrated as:

$$\beta_{li} = w\bar{l}_{fi}^k\left(\bar{P}_{c_i}\bar{h}_{c_i}\right)^{-1} \qquad \beta_{Ai} = 1 - \beta_{li}, \qquad (57)$$

The rental rate of land ($\bar{r}$) is the average based on the GCFS2 and GCFS3 datasets, shown in Table 1.

Given the value of $\bar{C}_i^k$, the subsistence level of consumption ($\bar{d}_i^k$) for *i*th staple food is calculated as the contribution of the *i*th staple food to the Recommended Daily Allowance (RDA_0) for calories. The RDA_0 is the minimum amount of energy needed to sufficiently meet the requirement that 97–98% of all individuals are healthy in every demographic. The study uses the RDA_0 value of 2080 kcal, estimated by UNHCR et al. (2004). The parameter $\bar{d}_i^k$ for the *i*th staple food is calibrated as:

$$\bar{d}_i^k = \omega^k(1-\varphi)\left(\frac{FS_i}{FS_0 \cdot KCL_i}\right) \cdot RDA_0 \cdot 365 \cdot POP_{GH} \quad (i = 1,\dots, 4), \qquad (58)$$

where FS_i and FS_0 are the daily caloric per capita food supply from the *i*th staple food and the total food supply, respectively, 365 is the number of days in a year, and POP_{GH} is the total population of Ghana.

With the subsistence level of consumption ($\bar{d}_i^k$) and household production ($\bar{h}_{c_i}^k$) known, the study then calibrates the value of the *i*th staple food (EXP_i) and total consumption (EXP_0) as;

$$EXP_i^k = \bar{P}_{C_i} \cdot \left(\bar{C}_i^k - \bar{d}_i^k - \bar{h}_{c_i}^k\right) \qquad (i = 1,\dots, 4), \qquad (59)$$

$$EXP_0^k = \sum_{i=1}^{4} EXP_i^k \cdot (\sum_{i=1}^{4} \delta_i)^{-1} , \quad (60)$$

$$EXP_5^k = EXP_0^k - \sum_{i=1}^{4} EXP_i^k , \quad (61)$$

where the parameter δ_i is the annual expenditure share of the i^{th} staple food taken as the average from the GLSS5 and GLSS6 datasets. Based on the calculated expenditure for staple foods and the composite good (EXP_5), the consumption share parameters are:

$$\alpha_i = EXP_i \cdot (EXP_0)^{-1}. \qquad (i = 1,\ldots, 5) \quad (62)$$

Rewriting equation *(12)*, the share parameter for leisure (α_6) is calibrated as:

$$\alpha_6 = \bar{C}_l^k \cdot \bar{w} \cdot \alpha_5 \cdot \left(\bar{P}_{C_5}, \cdot \bar{C}_5^k,\right)^{-1} , \quad (63)$$

The average time spent on leisure is computed as:

$$\bar{C}_l^k = \bar{t}^k - \bar{l}_{fo} - \sum_i^3 \bar{l}_{fi}, \quad (64)$$

The non-labor income parameter T^k is calibrated as the residual income such that the full-income constraint, equation *(7)*, holds with equality. Computing the average value of total household time and profits from cocoa production as $\bar{t}^k$ and $\bar{\pi}^k$, the parameter T^k is:

$$T^k = \bar{w}\bar{C}_6^k + \sum_{i=1}^{5} \bar{P}_{C_i} \bar{C}_i^k - \bar{w}\bar{\bar{t}}^k - \bar{\pi}^k , \quad (65)$$

where

$$\bar{\pi}^k = \omega^k \left(\bar{P}_c \bar{Q} - \bar{w}\bar{l} - \sum_{j=1}^{4} \bar{P}_{x_j}\bar{x}_j\right). \quad (66)$$

The residual food supply (S_{C_i}) and demand (D_{C_i}) of the i^{th} stable food from rest of Ghana are:

$$S_{C_i} = \left(\bar{Q}_{C_i} - \bar{h}_{C_i}^k\right)\left(\bar{P}_{C_i}{}^{\emptyset_i}\right)^{-1} , \quad (67)$$

$$D_{C_i} = \left(\bar{Q}_{C_i} - \bar{C}_i^k\right)\left(\bar{P}_{C_i}{}^{\eta_i}\right)^{-1}, \quad (68)$$

where the supply ($\emptyset_i$) and demand (η_i) elasticities are obtained from (Diao et al., 2008).

For the cocoa market, the average share ($\bar{\tau}$) of the world price received by farmers was calibrated as the average difference between the world price and farm-gate price for the period 2010-2013 obtained from Government of Ghana (2010). The demand and income elasticities for Ghanaian cocoa were taken as long-run values reported by the Consultative Board on the World Cocoa Economy[19] report on “Optimal” Export Taxes in Cocoa Producing Countries” (ICCO, 2008). These are also presented in Table 3. The scale parameter for the residual Ghanaian cocoa demand is

$$D_c = S_{C_{GH}}\left(P_c^{\eta_c} I^{\rho_c}\right)^{-1}, \qquad (69)$$

where $S_{C_{GH}}$ is total Ghanaian exports of cocoa given by total production, and I is the income parameter for cocoa consumption calibrated as the GNI of Europe and Central Asia (all income levels) - Ghana’s primary export region - for the period 2005-2010 as reported by World Bank (2014). The parameters η_c and ρ_c are the demand and income elasticities for Ghanaian cocoa obtained from ICCO (2008). It should be noted that the elasticity of demand for Ghanaian cocoa is inelastic (-0.9) meaning:

$$\partial TR_c / \partial P_c > 0. \qquad (70)$$

Hence as P_c drops due to increase in cocoa production (supply), cocoa farmers total revenue (TR_c) decreases.

[19] The creation of the Consultative Board on the World Cocoa Economy was one of the major innovations of the International Cocoa Agreement, 2001. The Board consists of private sector representatives of both exporting and importing Member countries whose mandate is to act in an advisory capacity to the International Cocoa Council on an extensive range of subjects (ICCO, 2015a).

Table 3: Calibrated Parameters (Cont.)

Utility function and budget parameters						
	Budget share (α_i)	Subsistence consumption (d_i) [a]			Other income and time	
		CLP	Non-CLP		CLP	Non-CLP
Cassava (C_1)	0.048	16.999	254.905	Total time	436.398	29.102
Yam (C_2)	0.036	12.289	184.276	Residual income	-3174.742	-211.712
Maize (C_3)	0.015	2.124	31.846			
Rice (C_4)	0.005	2.648	39.706			
Composite (C_5)	0.896	-	-			
Leisure (C_6)	0.186	-	-			

Production function parameters							
	Price (P_{x_j})	Input share in production (β_j)					
		Cocoa	Cassava ($C1$)	Yam ($C2$)	Maize ($C3$)		
Labor (l)	151.105	-	0.984	0.984	0.984		
Fertilizer (x_1)	2.086	0.263	0.016	0.016	0.016	CLP-I shocks	
Pesticide (x_2)	3.818	0.185	-	-		Participation	0.053
Chemicals (x_3)	33.874	0.089	-	-		Subsidy (ϑ)	0.360
Equipment (x_4)	154.068	0.120	-	-		Productivity (σ)	-0.039
Labor (l)	194.957	0.166	-	-	-		
		Productivity					
	CLP	38.046	741.040	312.320	313.866		
	Non-CLP	61.327	741.040	312.320	313.866		

[a] Indicates scaled parameters by 1,000,000
ROG = Rest of Ghana
ROG = Rest of the World
The ratio (φ) of the Ghanaian population (POP_{GH}) that produce cocoa is estimated at 0.126

The income parameter (I) and the cocoa market clearing condition (equation *(9.0)*) was estimated at US $16.666 trillion, representing the GNI of Europe and Central Asia (all income levels) for the period 2000/10 as reported by World Bank (2014)

Table 3: Calibrated Parameters

	Market clearing parameters						
	Elasticity			Demand [a]		Supply [a]	
	Demand	Supply	Income	ROG	ROW	ROG	ROW
Cassava (C_1)	-0.479	0.520	-	4155.430	-	20886.03	-
Yam (C_2)	-0.414	0.450	-	2733.826	-	5457.322	-
Maize (C_3)	-0.470	0.400	-	801.415	-	1611.278	-
Rice (C_4)	-0.953	0.400	-	435.116	-	563.290	-
Cocoa	-0.900	-	0.620	-	0.141	-	-

[a] Indicates scaled parameters by 1,000,000
ROG = Rest of Ghana
ROG = Rest of the World
The ratio (φ) of the Ghanaian population (POP_{GH}) that produce cocoa is estimated at 0.126
The income parameter (I) and the cocoa market clearing condition (equation *(9.0)*) was estimated at US $16.666 trillion, representing the GNI of Europe and Central Asia (all income levels) for the period 2000/10 as reported by World Bank (2014)

3. CLP-I implementation scenario

Following the completion of the CLP-I cocoa farmers that received the Full Package (FFS, FBS, and ICP), were trained in modern production and business practices and received fertilizer at a subsidized rate, which augmented these farmers' output. Also, demand has continued to outpace supply as consumer preferences shift toward darker chocolate, Asian middle class continues to grow, and income increases. Therefore, it is important to analyze the impact of this production and demand expansion on prices, quantities produced and consumed, and welfare for each of the five markets: cocoa, maize, rice, cassava, and yam.

For the simulation analysis, we numerically solve the system of 39 equations (*(11)-(17)*, *(26)*, and *(29)*) in 39 variables (C_i^k, l^k, l_{fi}^k, A_i^k, x_i^k, P_{C_i}, and P_c).[20,21] A baseline and counter factual scenario are run. The baseline scenario is without CLP-I and corresponds to the calibration. In the alternate scenario, CLP-I exposed farmers (k = 1) receive an input subsidy of 36% and a productivity shock of -3.9%, which corresponds to a 32% increase in yield, as estimated by Tsiboe et al. (2015).[22] Also, in the alternate scenario, in order to reflect pragmatic conditions in the world cocoa market, demand for cocoa expands as income (I) increases by 2.731% and demand (D_c) increases by 4.117%. For the period 2000-2010, the income increase is the average annual GNI growth rate for Europe and Central Asia (all income levels) (World Bank, 2014) and the demand expansion represents the average annual growth rate of the quantity of cocoa beans demand for grinding in the world also (ICCO, 2012b).[23]

The results of the baseline (see Table A1) and alternate scenarios are then compared to quantify the impact of the counterfactual scenario. Table 4 reports the simulation results for changes in endogenous variables and welfare impacts. Note that in the subsequent section, we perform sensitivity analysis on the farmer participation rate of CLP and the demand expansion.

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[20] These systems of equations were set up in MATLAB and solved numerically using the "fsolve" function package (MathWorks Inc, 2015).

[21] See Table A1 in the Appendix for the full systems of equations and their respective complementary variables and baseline values of the endogenous variables.

[22] The 36% input subsidy is obtained from Ndiaye et al. (2013).

[23] It should be noted that in computing these shock parameters, data recorded for the years 2008 and 2009 were not used. This was mainly because of the global reassertion during those periods.

Table 4: Simulation Results

	Cocoa	Cassava (C_1)	Yam (C_2)	Maize (C_3)	Rice (C_4)	Leisure (C_6)
Production change (%)						
CLP	31.564	0.321	-0.036	0.014	-	-
Non-CLP	3.427	0.290	0.427	0.540	-	-
ROG	-	0.000	0.000	0.000	0.003	-
Consumption change (%)						
CLP	-	1.088	0.831	1.093	0.437	1.434
Non-CLP	-	0.140	0.107	0.140	0.054	0.184
ROG	-	0.000	0.000	0.000	-0.007	-
ROW	5.186	-	-	-	-	-
Price change (%)	0.724	0.000	0.000	0.000	0.007	0.000
Production cost (%)						
CLP	32.517	-	-	-	-	-
Non-CLP	4.176	-	-	-	-	-

ROG and ROW indicates the rest of Ghana and the rest of the World, respectively
Baseline; Figures provided in Appendix Table A1
Simulation; CLP households experience a productivity shock of -0.039 and a subsidy of 0.360 on fertilizer coupled with an income shock of 2.731% and demand expansion of 4.117% in the world cocoa market.

Table 4: Simulation Results (Cont.)

	Cocoa	Cassava (C_1)	Yam (C_2)	Maize (C_3)	Rice (C_4)	Leisure (C_6)
Welfare analysis (US $/household)						
Change in consumer surplus						
CLP	-	0.041 (1.383)	0.033 (1.123)	0.014 (0.463)	-0.001 (-0.028)	-
Non-CLP	-	0.078 (0.178)	0.063 (0.144)	0.026 (0.059)	-0.005 (-0.011)	-
ROG	-	0.000 (0.000)	0.000 (0.000)	0.000 (0.000)	-0.031 (-0.008)	-
ROW	50.797	-	-	-	-	-
Change in producer surplus	-	-	-	-	-	
CLP	3.893 (132.707)	0.000 (0.000)	0.000 (0.000)	0.000 (0.000)	-	-
Non-CLP	7.497 (17.041)	0.000 (0.000)	0.000 (0.000)	0.000 (0.000)	-	-
ROG	-	0.000 (0.000)	0.000 (0.000)	0.000 (0.000)	0.035 (0.093)	-
Net welfare change	62.188	0.119 (1.561)	0.096 (1.267)	0.040 (0.522)	-0.002 (0.046)	-
Group specific welfare (US $/household)						

ROG and ROW indicates the rest of Ghana and the rest of the World, respectively
Baseline; Figures provided in Appendix Table A1
Simulation; CLP households experience a productivity shock of -0.039 and a subsidy of 0.360 on fertilizer coupled with an income shock of 2.731% and demand expansion of 4.117% in the world cocoa market.

Table 4: Simulation Results (Cont.)

Group specific welfare (US $/household)	
Net welfare change for non-cocoa households	0.004 (0.085)
Net welfare change for CLP households	3.980 (135.648)
Net welfare change for non-CLP households	7.660 (17.411)
Total CLP cost	4.430 (151.000)
Net welfare change in Ghana	11.643 (153.144)
Net welfare change in Ghana with CLP cost	7.213 (2.144)
Global net welfare change with CLP cost	58.011 (14.359)

ROG and ROW indicates the rest of Ghana and the rest of the World, respectively
Baseline; Figures provided in Appendix Table A1
Simulation; CLP households experience a productivity shock of -0.039 and a subsidy of 0.360 on fertilizer coupled with an income shock of 2.731% and demand expansion of 4.117% in the world cocoa market.

The results show that the implementation of CLP-I and demand shocks lead to a cocoa production increase for both CLP and non-CLP households of 31.564% and 3.427%, respectively, and a world quantity demand increase for Ghanaian cocoa of 5.186%. While CLP-I causes an outward shift in supply and downward pressure on the world cocoa price, the demand shocks cause an outward shift in demand and upward pressure on world price. The results show that the upward pressure on the world price outweighs the downward pressure, and the farm-gate cocoa price increases by 0.724%.[24]

Next, the spillover effects of CLP-I and demand expansion into the other Ghanaian food markets are considered. The results show that the cost of cocoa production increased for both

[24] Note that one objective of the marketing board is to project cocoa farmers from catastrophic drops in price. However, because the price is increasing, the marketing board would not intervene.

groups; however, because of the higher cocoa price, increased yields, and subsidized fertilizer price for CLP households', CLP households' income increased by 1.369%, while non-exposed household's income increased by only 0.176%. As the income of cocoa growing households rises, their demand for staple food and leisure shifts out. As a result, CLP households increase their consumption of cassava, yam, maize, rice, and leisure by 1.088%, 0.831%, 1.093%, 0.437%, and 1.434%, while the non-CLP households expand their consumption by only 0.140%, 0.107%, 0.140%, 0.054%, and 0.185%. Because the increase in income causes the demand for staple foods to shift out, there is also upward pressure on the food prices. For the staple foods—cassava, yam, and maize—produced by the cocoa household, any increase in consumption was met by an equal increase in production. As a result, market prices remain constant. Total household production of cassava and maize by CLP households increased by 0.321% and 0.014%, respectively. However, CLP households decreased their production of yam by 0.036%. For the non-CLP households, they increased production of cassava, yam, and maize by 0.290%, 0.427%, and 0.540%, respectively. For rice, the crop not produced by cocoa households, CLP households increase their consumption by 0.437%, while the non-CLP households expand their consumption by only 0.054%. Because an increase in income causes the demand for rice to shift out, there is also upward pressure on its market prices. This results in an expansion of the domestic rice supply by 0.003%, and a decline in the rest of Ghana (ROG) quantity demanded of 0.006%. As a result, the equilibrium price for rice increase by 0.007%.

Next, the effects of the counterfactual scenario on welfare, based on equations (*34*)-(*47*) are examined. Because of the higher price and increased production of cocoa, producer surplus per household for CLP and non-CLP households increases by US $132.707 and US $17.041 (equation *(34)*), respectively. The outward shift in demand and higher consumption, despite the higher world cocoa price, leads to an increased consumer surplus for ROW of US $50.797 million (equation *(38)*). Recall that in order to compute a meaningful value for ΔCS_c, a maximum world cocoa price (P_c^*) of 5.265 US $/kg is imposed. Furthermore, a 10% increase or decrease in this price has minimal impact on consumer surplus for cocoa (ΔCS_c^*). Therefore, the overall welfare gain for the cocoa (world demand and local production) market is US $62.187 million.

For the cassava, yam, and maize markets, because of the increase in income and higher consumption, the gain in consumer surplus per household for CLP (non-CLP) households is highest for cassava at US $1.383 (US $0.178), followed by yams at US $1.123 (US $0.144), and then maize at US $0.463(US $0.049) (equation *(44)*). Because of higher prices for rice and constant income for non-cocoa producers in Ghana, consumer surplus per household for rice declines, with the largest drop for CLP households at US $0.028, followed by non-CLP households at US $0.011, and then ROG at US $0.008. However, due to the higher rice prices and expanded production, producer surplus per household for rice rises by US $0.093 (equation *(12.3)*). The overall welfare change per household for the domestic food markets (maize, rice, cassava, and yam) is US $3.396.

As discussed in the introduction, Norton et al. (2013) and Tsiboe et al. (2015) and estimated the benefit-cost ratio of CLP-I to be US$ 80 and US$ 18, respectively, for every dollar spent on human capital development. In computing their benefit-cost ratios, Norton et al. (2013) and Tsiboe et al. (2015) estimated the cost of CLP-I per beneficiary at US $252 and US $151, respectively. This indicates that the program training costs have decreased over time as training mechanisms have become more efficient and more farmers have been reached. This study adopts Tsiboe et al. (2015)'s estimate of CLP-I cost per household. Given the total cost of CLP-I implementation per household in Ghana and the changes in consumer and producer surpluses above, the overall welfare measure associated with CLP-I (CLP_{welfare}) is calculated by subtracting the cost from the net welfare change in Ghana or from the Global net welfare gain, giving a net welfare of US $7.213 million (US $2.144 per household) for Ghana and US $58.010 million globally.

4. Sensitivity analysis

CLP Phase II (CLP-II) is set to take place over the period February 2014 to January 2019 with the key objective of expanding the number of farm households that receive the full package (FFS, FBS, and ICP). Based on the success of CLP-I, CLP-II will utilize matching grants from industry and government partners to expand the coverage of current beneficiary CLP-I households in West and Central Africa from the current number of reached households of 106,000 to 200,000 by 2018.[25] Also, the amount by which demand expands as consumers' preference for darker chocolate and the Asian middle continue to grow is not clear. Consequently, we performed two sensitivity analyses. For the first sensitivity analysis, this study implements an ex ante examination of CLP-II. For the second sensitivity analysis, this study consider demand expansion by changing the demand residual D_c.

In order to undertake an ex ante analysis of CLP-II on the cocoa and food markets (maize, rice, cassava, and yam), we perform a sensitivity analysis around the percentage of Ghanaian cocoa growing households that participate in CLP training (ω^k), holding all other

[25] Under CLP-II, farmer outreach will be the sole responsibility of industry and government partners by continuing to scale up the best practices of CLP-I, with WCF providing additional support in the form of design support, technical assistance, and oversight from the program staff. In addition to this, WCF will work to improve the capacity of the industry and government partners to carry out monitoring and evaluation of CLP-II and facilitate partnerships that will enable the sharing of best practices. Ultimately, the new model will lead to a full transition of interventions in the cocoa sector to public and private players (WCF, 2013).

assumptions based on the CLP-I scenario constant. Currently only 6.250% of cocoa growing households in Ghana have been exposed to the full CLP-I package. Figure 1 shows the results for incrementally changes in percentage of CLP exposed households from 1% to 99% through repeated intervals of 1%. The analysis shows that for every 1% increase CLP participation, world cocoa price on average decreases by 0.001%. From Figure 1 (A) (see Figure 1 (B) for the aggregate trends), producer surplus per household for the CLP participating households decreases at an increasing rate for CLP participation rates lower than 40%, then the decline starts to decreases at a decreasing rate until producer surplus per household reaches US $17.546. The nonlinear relationship of the CLP participation rate to CLP cocoa producer surplus per household is partly explained by the fact that, while overall supply of Ghanaian cocoa shifts out, world demand for Ghanaian cocoa stays constant, which leads to a price decline. Contrary to the CLP participating households, producer surplus per household for the non-CLP participating households tends to decline at a decreasing rate as CLP participation increases until producer surplus reaches negative US $305.991. It should also be noted that surplus per household for the CLP participating households are always larger than that non-CLP participating households at every conceivable participation rate.

As shown on Figure 1 (B), aggregate consumer surplus for cocoa increases with CLP participation as a result of the declining world price for cocoa. The participation rate at which net Ghanaian welfare per household is equal to CLP cost (breakeven point) is about 59% (Figure 1 (A)).

Figure 1: Sensitivity Analysis of Key Welfare Indicators for CLP program expansion

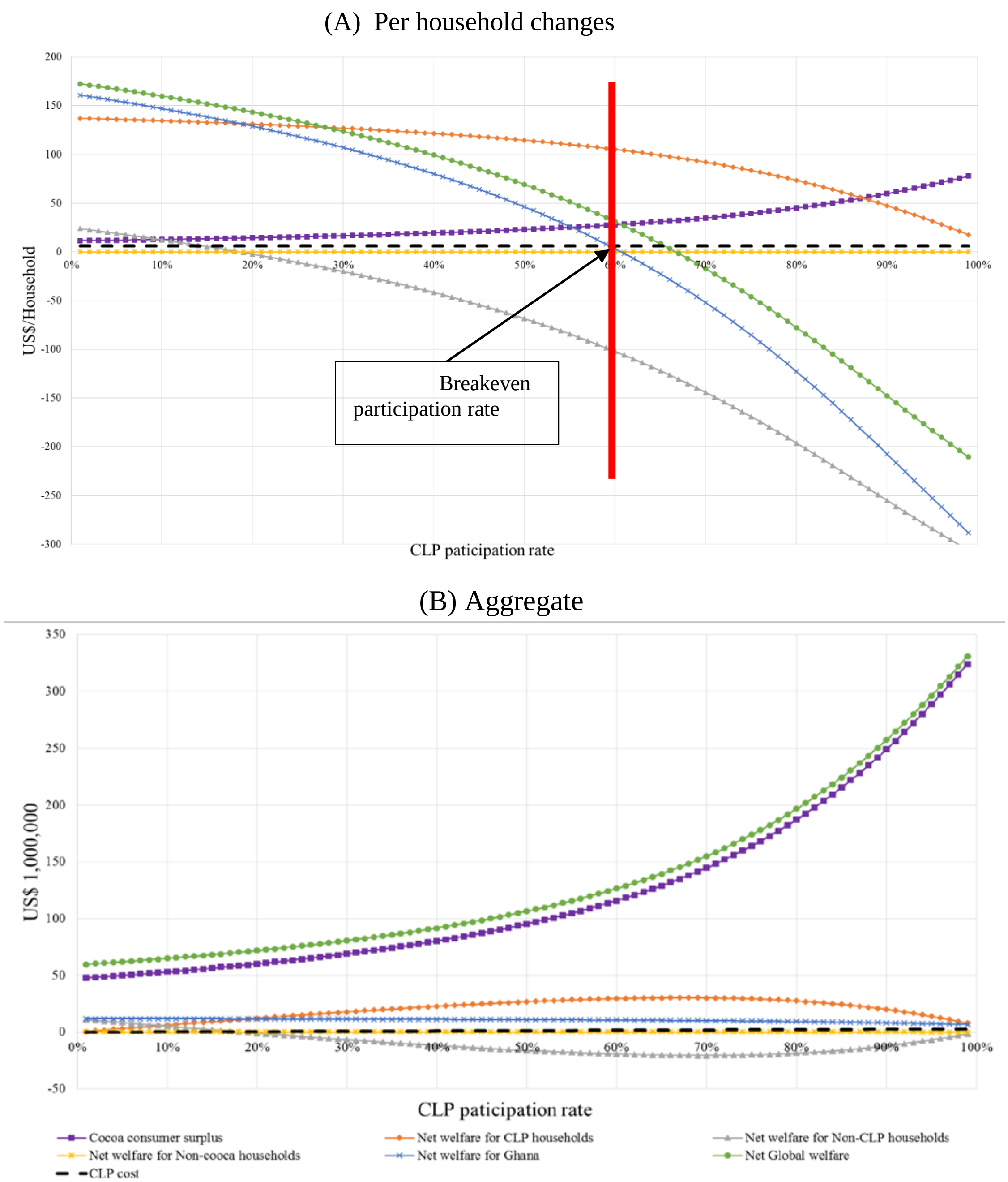
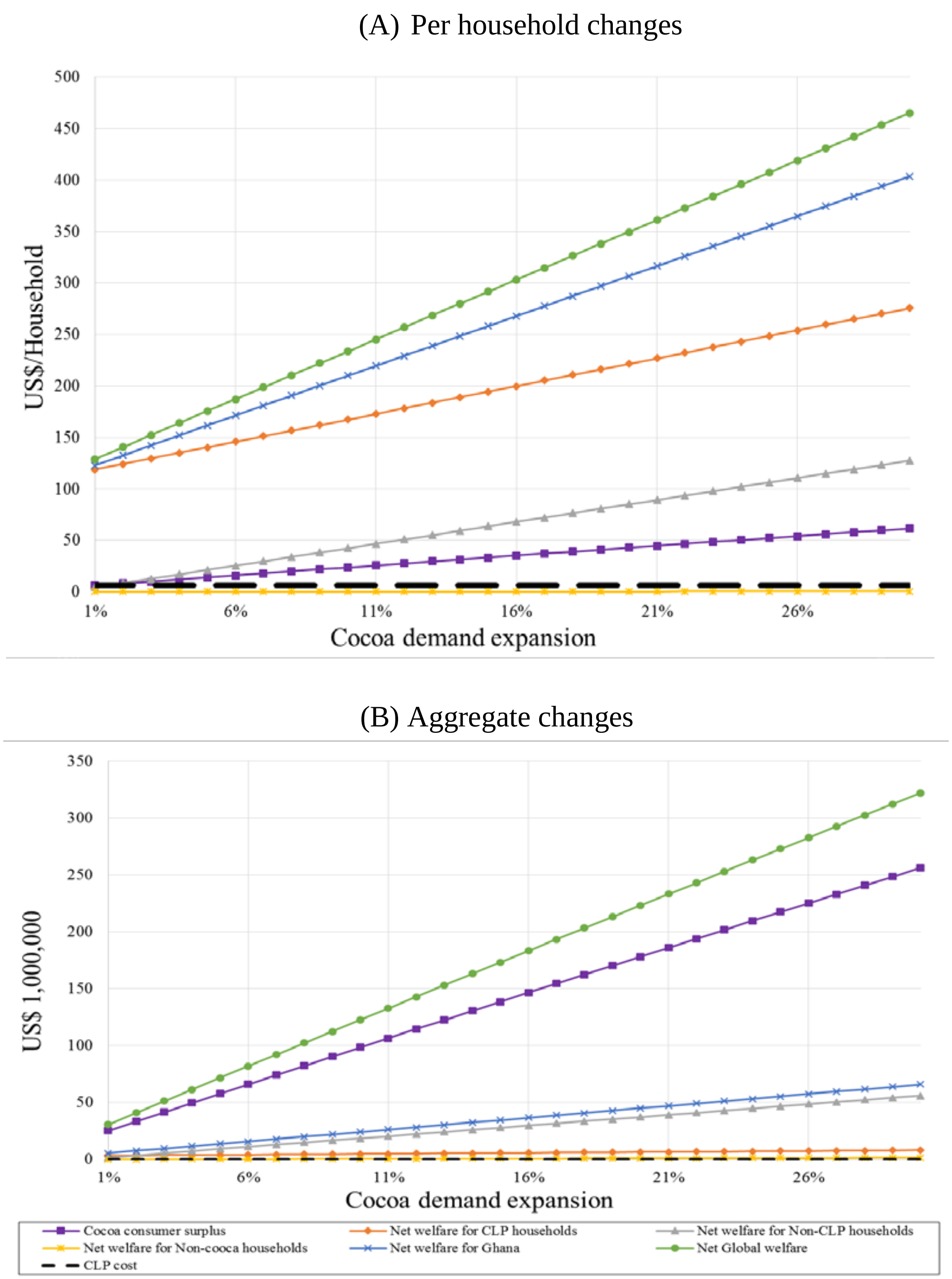


Figure shows incrementally changes of CLP participation holding all other assumptions based on the CLP-I scenario constant.

Figure 2: Sensitivity Analysis of Key Welfare Indicators

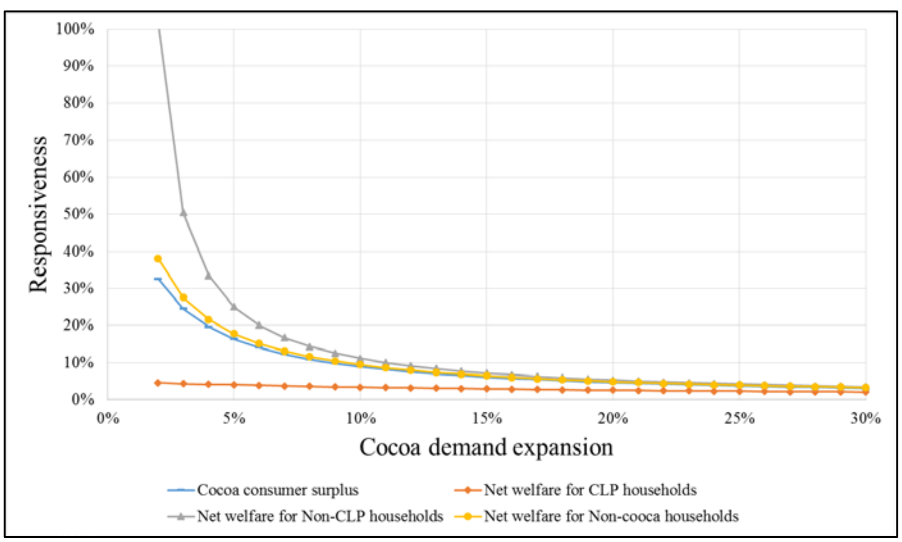


The figure shows incrementally changes in the residual demand for Ghanaian cocoa on the world market holding all other assumptions based on the CLP-I scenario constant.

he second sensitivity analysis considers incremental increases to the residual demand for Ghanaian cocoa in the world market, again holding all other assumptions for CLP-I scenario constant. Figure 2 graphs the results for increasing the scale parameter D_c by 0% to 20% for repeated intervals of 1%. Contrary to the first sensitivity analysis, this result shows that for every 1% increase in demand, world cocoa price on average rises by 0.002%. As shown in Figure 2 (A) and (B), there are sustained gains for all six welfare indicators. With total CLP cost held constant, the total welfare for Ghana and the World increase linearly.

Figure 3 shows the responsiveness of welfare for CLP and non-CLP households, cocoa consumers, and non-cocoa growing households to cocoa demand expansion, i.e., the percentage change in these welfare indicators to a percentage change in cocoa demand. The figure shows that producer surplus for the non-CLP participating households is the most responsive to demand expansion at about 0.138% for every 1% increase in demand. This is followed by welfare for non-cocoa households (0.092%), Cocoa consumer surplus (0.085%), and then that producer surplus for the CLP participating households (0.029%).

Figure 3: Responsiveness of selected welfare indicators to cocoa demand expansion



Further analysis of the responsiveness of the breakeven participation rate in Ghana (the point where net Ghanaian welfare is equal to CLP cost) to cocoa demand expansion showed that for every 1% increase in demand, the breakeven CLP participation rate increases by 3.55%. Finally, the analysis on the breakeven participation rate also revealed that, in order to implement CLP-II, cocoa demand must expand by at least 2%, otherwise the net gains from the program will not fully cover the programs total costs. This analysis demonstrates the importance of marketing and demand expansion when trying to raise the income and welfare of cash crop farmers.

F. Conclusions and Recommendations

Building on the yield increases due to CLP-I estimated in Tsiboe et al. (2015), this study utilized the Farm Household Model to evaluate the cocoa market outcome and the spillover effects of CLP-I (a WCF project aimed at doubling the income of cocoa-growing households in Sub-Saharan Africa) in Ghana. This study also performs an ex ante analysis of CLP-II and demand expansion based on the known results of farmers participating in CLP-I. Due to a 36% increase in yield due to CLP-I and an increase of world income of 2.731% annually and cocoa demand expansion of 4.117%, the results show that (i) the price of cocoa increases by 0.724%, (ii) both CLP and non-CLP households benefit, with CLP households experiencing larger gains, (iii) non-cocoa farmers who consume rice suffer due to high price, (iv) rice producers' benefit from increased demand by cocoa farmers and higher prices, and (iv) the net benefit of CLP-I to Ghana and the world are both positive.

Results from the ex-ante analysis of CLP-II showed that: (i) cocoa price responds negatively to CLP participation rate and positively to world cocoa demand expansion, (ii) even though the gains to both CLP and non-CLP decline with CLP participation, the benefits to the former is always higher than to the later, and is never negative, (iii) the participation rate necessary for net Ghanaian welfare to equal CLP cost is estimated at about 59%. The results of the sensitivity analysis for demand expansion shows that (i) welfare for non-CLP households is more responsive to demand expansion relative to the CLP households, (ii) breakeven participation rate in Ghana responds positively to demand expansion ,(iii) there are sustained gains welfare as cocoa demand expands.

This study demonstrates the relevance of the FHM for conducting a holistic impact analysis of a development programs such as the CLP, while taking into account the key features of low-income economies. The model developed in this study analyzes the production and consumption decisions for a representative farm household that grows a cash crop and other staple foods for subsistence consumption and the spillover effects into other food markets. However, the model presented here suffers from two main limitations which suggest natural extensions of the current study and important topics for additional research. First, the study models the residual demand for Ghanaian cocoa, as such it does not account for the supply response of other cocoa exporting countries to changes in the world cocoa price. Secondly, CLP is currently being implemented in Cameroon, Côte d'Ivoire, Ghana, Liberia, and Nigeria, hence extending the currently model to include these four countries to examine how they interact in the world market is important.

Notwithstanding these limitations, the results show that there is still room for CLP to be expanded such that net welfare in Ghana and the world are positive. Any participation beyond 59%, will mean that net benefits form the program could be negative for Ghana. Therefore, WCF must consider that, if demand is inelastic—as most agricultural goods are—expanding production will lead to a revenue loss, unless demand also increases. Hence, marketing and demand expansion are equally as, if not more, important than production expansion to increase rural farm household income and welfare. Given Asian is largely an untapped market and the rising middle class, this is a crucial time to promote Ghanaian cocoa and establish supply links in this burgeoning Asian market.

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Appendix: Supplemental Material

Table A1: Full systems of equations formulated for the FHM for cocoa farmers in Ghana

Equation	Solved variable	Baseline value
Consumer choices non-CLP farm households		
$\alpha_1 C_5^0\left(\alpha_5(C_1^0-d_1^0)\right)^{-1}-P_{C_1}\left(P_{C_5}\right)^{-1}=0$	C_1^0	1054.444 [a]
$\alpha_2 C_5^0\left(\alpha_5(C_2^0-d_2^0)\right)^{-1}-P_{C_2}\left(P_{C_5}\right)^{-1}=0$	C_2^0	437.849 [a]
$\alpha_3 C_5^0\left(\alpha_5(C_3^0-d_3^0)\right)^{-1}-P_{C_3}\left(P_{C_5}\right)^{-1}=0$	C_3^0	133.890 [a]
$\alpha_4 C_5^0\left(\alpha_5(C_4^0-d_4^0)\right)^{-1}-P_{C_4}\left(P_{C_5}\right)^{-1}=0$	C_4^0	57.201 [a]
$\alpha_6 C_5^0\left(\alpha_5(C_6^0-d_6^0)\right)^{-1}-P_{C_6}\left(P_{C_5}\right)^{-1}=0$	C_6^0	306.135 [a]
Consumer choices CLP farm households		
$\alpha_1 C_5^1\left(\alpha_5(C_1^1-d_1^1)\right)^{-1}-P_{C_1}\left(P_{C_5}\right)^{-1}=0$	C_1^1	70.317 [a]
$\alpha_2 C_5^1\left(\alpha_5(C_2^1-d_2^1)\right)^{-1}-P_{C_2}\left(P_{C_5}\right)^{-1}=0$	C_2^1	29.199 [a]
$\alpha_3 C_5^1\left(\alpha_5(C_3^1-d_3^1)\right)^{-1}-P_{C_3}\left(P_{C_5}\right)^{-1}=0$	C_3^1	8.929 [a]
$\alpha_4 C_5^1\left(\alpha_5(C_4^1-d_4^1)\right)^{-1}-P_{C_4}\left(P_{C_5}\right)^{-1}=0$	C_4^1	3.815 [a]
$\alpha_6 C_5^1\left(\alpha_5(C_6^1-d_6^1)\right)^{-1}-P_{C_6}\left(P_{C_5}\right)^{-1}=0$	C_6^1	20.415 [a]
Cocoa production choices for non-CLP farm households		
$\beta_l P_c z^0\ (l^0)^{\beta_l-1}(x_1^0)^{\beta_1}(x_2^0)^{\beta_2}(x_3^0)^{\beta_3}(x_4^0)^{\beta_4}-w\ \ =0$	l^0	128.343 [a]
$\beta_1 P_c z^0\ (l^0)^{\beta_l}(x_1^0)^{\beta_1-1}(x_2^0)^{\beta_2}(x_3^0)^{\beta_3}(x_4^0)^{\beta_4}-P_{x_1}=0$	x_1^0	49.339 [a]
$\beta_2 P_c z^0\ (l^0)^{\beta_l}(x_1^0)^{\beta_1}(x_2^0)^{\beta_2-1}(x_3^0)^{\beta_3}(x_4^0)^{\beta_4}-P_{x_2}=0$	x_2^0	2.686 [a]
$\beta_3 P_c z^0\ (l^0)^{\beta_l}(x_1^0)^{\beta_1}(x_2^0)^{\beta_2}(x_3^0)^{\beta_3-1}(x_4^0)^{\beta_4}-P_{x_3}=0$	x_3^0	0.794 [a]
$\beta_4 P_c z^0\ (l^0)^{\beta_l}(x_1^0)^{\beta_1}(x_2^0)^{\beta_2}(x_3^0)^{\beta_3}(x_4^0)^{\beta_4-1}-P_{x_4}=0$	x_4^0	0.869 [a]

[a] Indicates scaled values by 1,000,000

Table A1: Full systems of equations formulated for the FHM for cocoa farmers in Ghana (Cont.)

Equation	Solved variable	Baseline value [a]
Cocoa production choices for CLP farm households		
$\beta_l P_c z^1\ (l^1)^{\beta_l - 1}(x_1^1)^{\beta_1}(x_2^1)^{\beta_2}(x_3^1)^{\beta_3}(x_4^1)^{\beta_4} - w \quad = 0$	l^1	8.559 [a]
$\beta_1 P_c z^1\ (l^1)^{\beta_l}(x_1^1)^{\beta_1 - 1}(x_2^1)^{\beta_2}(x_3^1)^{\beta_3}(x_4^1)^{\beta_4} - (1-\vartheta)P_{x_1} = 0$	x_1^1	3.290 [a]
$\beta_2 P_c z^1\ (l^1)^{\beta_l}(x_1^1)^{\beta_1}(x_2^1)^{\beta_2 - 1}(x_3^1)^{\beta_3}(x_4^1)^{\beta_4} - P_{x_2} = 0$	x_2^1	0.179 [a]
$\beta_3 P_c z^1\ (l^1)^{\beta_l}(x_1^1)^{\beta_1}(x_2^1)^{\beta_2}(x_3^1)^{\beta_3 - 1}(x_4^1)^{\beta_4} - P_{x_3} = 0$	x_3^1	0.053 [a]
$\beta_4 P_c z^1\ (l^1)^{\beta_l}(x_1^1)^{\beta_1}(x_2^1)^{\beta_2}(x_3^1)^{\beta_3}(x_4^1)^{\beta_4 - 1} - P_{x_4} = 0$	x_4^1	0.058 [a]
Staple food production choices for non-CLP farm households		
$\beta_{l1} P_{C_1} z_1^0 (l_{f1}^0)^{\beta_{l1} - 1}(A_1^0)^{\beta_{A1}} - w = 0$	l_{f1}^0	1.112 [a]
$\beta_{A1} P_{C_1} z_1^0 (l_{f1}^0)^{\beta_{l1}}(A_1^0)^{\beta_{A1} - 1} - r = 0$	A_1^0	0.967 [a]
$\beta_{l2} P_{C_2} z_2^0 (l_{f2}^0)^{\beta_{l2} - 1}(A_2^0)^{\beta_{A2}} - w = 0$	l_{f2}^0	0.614 [a]
$\beta_{A2} P_{C_2} z_2^0 (l_{f2}^0)^{\beta_{l2}}(A_2^0)^{\beta_{A2} - 1} - r = 0$	A_2^0	0.534 [a]
$\beta_{l3} P_{C_3} z_3^0 (l_{f3}^0)^{\beta_{l3} - 1}(A_3^0)^{\beta_{A3}} - w = 0$	l_{f3}^0	0.193 [a]
$\beta_{A3} P_{C_3} z_3^0 (l_{f3}^0)^{\beta_{l3}}(A_3^0)^{\beta_{A3} - 1} - r = 0$	A_3^0	0.168 [a]
Staple food production choices for non-CLP farm households		
$\beta_{l1} P_{C_1} z_1^1 (l_{f1}^1)^{\beta_{l1} - 1}(A_1^1)^{\beta_{A1}} - w = 0$	l_{f1}^1	0.074 [a]
$\beta_{A1} P_{C_1} z_1^1 (l_{f1}^1)^{\beta_{l1}}(A_1^1)^{\beta_{A1} - 1} - r = 0$	A_1^1	0.065 [a]
$\beta_{l2} P_{C_2} z_2^1 (l_{f2}^1)^{\beta_{l2} - 1}(A_2^1)^{\beta_{A2}} - w = 0$	l_{f2}^1	0.041 [a]
$\beta_{A2} P_{C_2} z_2^1 (l_{f2}^1)^{\beta_{l2}}(A_2^1)^{\beta_{A2} - 1} - r = 0$	A_2^1	0.036 [a]
$\beta_{l3} P_{C_3} z_3^1 (l_{f3}^1)^{\beta_{l3} - 1}(A_3^1)^{\beta_{A3}} - w = 0$	l_{f3}^1	0.013 [a]
$\beta_{A3} P_{C_3} z_3^1 (l_{f3}^1)^{\beta_{l3}}(A_3^1)^{\beta_{A3} - 1} - r = 0$	A_3^1	0.011 [a]

[a] Indicates scaled values by 1,000,000

Table A1: Full systems of equations formulated for the FHM for cocoa farmers in Ghana (Cont.)

Equation	Solved variable	Baseline value [a]
Budget constraint non-CLP farm households		
$w\bar{t}^0 + P_c z^0 (l^1)^{\beta_l} \prod_{j=1}^{4} \left(x_j^0\right)^{\beta_j} + T^0 - \left(w(C_6^0 + l^0) + \sum_{j=1}^{4} P_{x_j} x_j^0 + \sum_{i=1}^{5} P_{C_i} C_i^0\right) = 0$	C_5^0	3076.398 [a]
Budget constraint CLP farm households		
$w\bar{t}^1 + P_c\left(z^1(1+\sigma)\right)(l^1)^{\beta_l} \prod_{j=1}^{4} \left(x_j^1\right)^{\beta_j} + T^1 - \left(w(C_6^1 + l^1) + \left((1-\vartheta)x_j^1 P_{x_j}\right) + \sum_{j=1}^{4} P_{x_j} x_j^1 + \sum_{i=1}^{5} P_{C_i} C_i^1\right) = 0$	C_5^1	205.154 [a]
Market clearing conditions		
$S_{C_1} P_{C_1}^{\emptyset_1} + h_{c_1}^0 + h_{c_1}^1 - \left(D_{C_1} P_{C_1}^{-\eta_1} + C_1^0 + C_1^1\right) = 0$	P_{C_1}	0.207
$S_{C_2} P_{C_2}^{\emptyset_2} + h_{c_2}^0 + h_{c_2}^1 - \left(D_{C_2} P_{C_2}^{-\eta_2} + C_2^0 + C_2^1\right) = 0$	P_{C_2}	0.490
$S_{C_3} P_{C_3}^{\emptyset_3} + h_{c_3}^0 + h_{c_3}^1 - \left(D_{C_3} P_{C_3}^{-\eta_3} + C_3^0 + C_3^1\right) = 0$	P_{C_3}	0.488
$S_{C_4} P_{C_4}^{\emptyset_4} + h_{c_4}^0 + h_{c_4}^1 - \left(D_{C_4} P_{C_4}^{-\eta_4} + C_4^0 + C_4^1\right) = 0$	P_{C_4}	0.903
$\left((1.003)D_c\right)P_c^{-\eta_c}\left((1+1.003)I\right)^{\rho_c} - P_c z^0 (l^1)^{\beta_l} \prod_{j=1}^{4} \left(x_j^0\right)^{\beta_j} - \left(z^1(1+\sigma)\right)(l^1)^{\beta_l} \prod_{j=1}^{4} \left(x_j^1\right)^{\beta_j} = 0$	P_c	2.170

[a] Indicates scaled values by 1,000,000

IV. Conclusion

This thesis consists of two studies analyzing the Cocoa Livelihood Program (CLP-I)—a current World Cocoa Foundation (WCF) development program implemented in 2009. The first paper uses a difference-in-differences econometric model to estimate the impact of CLP on yield. The econometric analysis employs data from 2,048 on-the-ground farm surveys in Ghana, Côte d'Ivoire, Nigeria, and Cameroon, from pre- and post- CLP-I intervention periods (2009/10 and 2012/13 growing seasons). The results show that yield enhancements attributable to CLP-I are 32%, 34%, 50% and 62% in Ghana, Côte d'Ivoire, Nigeria and Cameroon, respectively. Using a total program cost of US $151- US $200 per beneficiary and estimated annual benefits of US $109- US $322 per beneficiary over 25 years, the benefit-cost ratios of CLP-I was estimated to range from US $18- US $62 for every dollar spent on human capital development.

Building on the yield enhancement due to CLP-I estimated from the econometric analysis in the first study, the second study develops a Farm Household Model to simulate the impact of CLP-I in Ghana and demand expansion on equilibrium price and quantities and welfare. With a yield increase of 32% in Ghana and an expansion of world income of 2.731% and cocoa demand expansion of 4.117% the results show that (i) both CLP and non-CLP households benefit, with CLP households experiencing larger gains, (ii) non-cocoa farmers who consume rice suffer due to high price, assuming they experience no income increase, (iii) rice producers' benefit from increased demand by cocoa farmers and higher prices, and (iv) the net benefit of CLP-I to Ghana and the world are both positive. The sensitivity analysis showed that: (i) cocoa price responds negatively to CLP participation rate (CLP-II) and positively to world cocoa demand expansion, (ii) the benefits to CLP households is always higher than that of the non-CLP households and, even though they both decline with CLP participation, they are never negative, (iii) the participation rate necessary for net Ghanaian welfare is equal to CLP cost is estimated at about 7.750%, and (iv) there are sustained gains welfare as cocoa demand expands.

Contrary to Diegert et al. (2014) and supporting the work of Norton et al. (2013), the results from the two studies show that the CLP indeed increase yields and profit in the region, and that there is still room for CLP to be expanded such that net welfare is positive. The results also suggest the WCF should endeavor to increase the number of farmers who receive all, not some, of the components of the program. This would not only help ensure that each producer obtains as much human capital as possible from each of the training programs, but increases the probability of reaching the CLP goal of doubling the income of 200,000 smallholder cocoa-growing households in Ghana, Côte d'Ivoire, Nigeria and Cameron. However for Ghana any participation rate beyond 59%, will mean that net benefits form the program could be negative. Therefore WCF must consider that, if demand is inelastic—as most agricultural goods are—expanding production will lead to a revenue loss, unless demand also increases. Hence, they should focus on marketing and demand expansion as well as production expansion to increase rural farm household income.

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