INTERNATIONAL CONFERENCE OF AGRICULTURAL ECONOMISTS
ICAE
29th | Milan Italy 2015
UNIVERSITÀ DEGLI STUDI DI MILANO AUGUST 8 - 14
AGRICULTURE IN AN INTERCONNECTED WORLD

UTZ certification for groups of smallholder coffee farmers: Hype of hope?

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Abstract

In the recent past the coffee production sector witnessed a rapid expansion of certification programs promoting voluntary sustainability standards, one of which is UTZ Certified. In this article we assess the impact that this program has on participating smallholder farmers by reviewing the results of an agent-based simulation for modeling rural producer organizations. We present the developed empirical simulation model by sharing the common protocol, which documents the structure the applied simulation tool and its parameterization for the group of coffee farmers, and reporting the results of model validation. The main strength of this assessment is that it considers certification-related costs of the farmers, which are ignored in the analyses available so far. The obtained simulation results constitute quantitative evidence of UTZ certification being able to create considerable positive impacts on the participating farmers. The results outline the importance of external financing and supportive measures complementing certification in groups.

Keywords: commercialization, rural producer organizations, multi-agent systems, sustainability standards, Uganda

JEL codes: C61, C63, D12, Q12, Q13

1. Introduction

The recent scientific literature (Shiferaw et al., 2011; Markelova and Mwangi, 2010; Markelova et al., 2009; Shiferaw et al., 2008) underlines the importance of rural producer organizations (RPO) in providing better market access and advancing the commercialization of agricultural activities for smallholder farmers in developing countries. One way by which an RPO may serve its member farmers is through participation in sustainability certification schemes for agricultural products. In this case, farmers are supposed to directly benefit from certification by achieving price premiums and better linkages with global commodity markets. However, there are costs associated with training, monitoring, purchasing equipment, and complying with sustainability standards that farmers and RPO participating in certification schemes have to bear in order to be able to sell their products as certified. Hence, the participation of smallholders in certification programs promoting voluntary sustainability standards (VSS) will result in livelihood improvement only when the benefits outweigh the entry and running costs of the certification programs.

For the coffee production sector, VSS experienced a notoriously rapid expansion in the recent past (Potts et al., 2014). Standard-compliant coffee evolved from a niche to a mainstream product, with approximately 40% of coffee in the world being produced in compliance with VSS (Potts et al., 2014). During the last two decades a number of certification initiatives have appeared in the coffee market, such as Fairtrade, Organic, Rainforest Alliance, UTZ Certified and others. The impacts that these emerging standards have on participating households and RPO has yet to be quantified consistently, since existing studies generally do not fully consider the costs of certification and often lack control groups (Kolk, 2013). Moreover, the majority of the existing studies are dedicated solely to Fairtrade (Kolk, 2013). In terms of relatively newer initiatives, such as UTZ Certified (started as Utz Kapeh Foundation in 2002), there is a lack of detailed quantitative evidence of its impact on smallholder producers. The publicly available analyses of UTZ certification that we found so far (El Ouaamari and Cochet, 2014; Potts et al., 2014; Raynolds et al., 2007; Kilian et al., 2004) focus either on a qualitative discussion of certification goals and requirements or providing the reported price premiums.

Meanwhile, UTZ Certified is nowadays one of the most prominent VSS for coffee. This sustainability program is focused on promotion of good farm-level production practices while supporting farm profitability and improvement of market transparency and product traceability. In 2012, around 190 thousand metric tons of coffee were sold under the UTZ Certified label, making it the largest VSS for coffee in terms of sales volume (Potts et al., 2014). Given the importance of UTZ certification for the coffee production sector, we identified the absence of detailed quantitative data of its influence on rural producers as a significant knowledge gap. Our article targets this gap by conducting an assessment of the efficiency of RPO involvement in rural Uganda for the case of UTZ certification. We assess both implemented and alternative set-ups of UTZ certification that differ in terms of financing of entry and running costs, the number of farmers initially included, and the repayment period for initial investment. Also, based on our analysis, we provide an estimate of the maximum potential impact of UTZ certification for smallholder coffee producers in Uganda.

As a research methodology for our impact assessment, we applied simulation modeling using an empirical application of the agent-based software MPMAS (Schreinemachers and Berger, 2011). The application[1] was developed for simulating the functioning of RPO of rural farmers in Uganda. The main features and the validity of the application are discussed in this article.

Based on the results of our assessment, we present conclusions on the role of UTZ certification in improving the commercialization of rural producers, propose ways for improving the ongoing certification program and discuss the long-term sustainability of the scheme. The results communicated in this paper are, therefore, valuable for certification providers, RPO managers, NGO, decision makers of various levels, as well as for the broader audience interested in the topics of smallholder market access and commercialization, as they provide information on the effectiveness of UTZ sustainability certification in improving the incomes of smallholder farmers.

2. Research Setting and Case Study

2.1. *Research Project*

This study was conducted as part of the international research project, "Working together for market access: Strengthening rural producer organizations in Sub-Saharan Africa" funded by the German Federal Ministry of Economic Cooperation (BMZ) and led by the International Food Policy Research Institute (IFPRI). The project activities concentrated on the investigation of RPO by analyzing their abilities for improving market access and livelihoods of their members. The aim of the project was to propose viable measures at the level of the RPO that could support commercialization and income of rural farmers and assess the impacts of these measures by conducting field and virtual (i.e. computer simulation) experiments.

At the end of 2009/beginning of 2010, IFPRI conducted focus groups (Dejene-Aredo et al., 2009) and a baseline project survey in Uganda (IFPRI, 2010), which approached members and administrations of RPO. In March-April 2011 we carried out participatory research in Uganda involving managers of RPO, regular RPO members and key expert informants related to the cooperative sector. Based on the results of the survey and the participatory research we created an

[1] Both, the software package and its technical documentation are available for download from https://mp-mas.uni-hohenheim.de

application of MPMAS software (MPMAS Uganda) that is suited for simulating decision-making and functioning of farmers and RPO from the Lake Victoria Crescent area of Uganda and is able to project the possible future effects of various RPO actions (e.g. engaging in group certification, organizing payments "on-the-spot", etc) through scenario-based analysis.

2.2. *Coffee Market and Rural Producer Organizations in Uganda*

Coffee is the most important cash crop in Uganda and the country's main export commodity, comprising 15.1% of the total value of Ugandan formal exports (BOU, 2013). In 2012 Uganda was the second largest coffee producer in Africa and the 11th largest in the world: in 2012 coffee plantations in Uganda occupied 310,000 hectares and yielded 186,126 tones of green coffee FAOSTAT (2014). Baffes (2006) estimated that coffee in Uganda is grown on approximately 500,000 farms. Most of these are smallholders: 70.3% of coffee-growing households have less than 5 acres of land (Hill, 2010). Their livelihoods are heavily dependent on the coffee value chain (UCTF, 2010). Therefore, a potential value addition through sustainability certification for coffee could influence a large portion of the country's rural population.

The vast share of coffee produced in Uganda (96.8% in agricultural year 2011/2012, according to ICO, 2014) is exported. The main destinations for Ugandan coffee exports are developed countries. According to the latest statistics, 72.3% of the coffee exported from Uganda goes to European Union countries and another 6.8% to United States, Switzerland, South Korea and Japan (UCDA, 2014). Therefore, given the growing consumer demand for sustainably produced coffee products in developed countries (Potts et al., 2014; Reinecke et al., 2012; Manning et al., 2012), VSS certification for coffee can be considered as a promising opportunity in increasing the value of agricultural production and exports in the Ugandan context.

The market liberalization reforms in Uganda that took place in the 1990s caused a later emergence of member-owned grassroots RPO in the country (Kwapong and Korugyendo, 2010; Mrema, 2008). These RPO are especially common in the local coffee sector (Kwapong and Korugyendo, 2010; Dejene-Aredo et al., 2009; Masiga and Ruhweza, 2007). They organize collective marketing of smallholder produce, thus enabling them to reach economies of scale and negotiate better bargains through bypassing local middlemen. As was confirmed during our research, producers are usually organized in RPO on two levels: (i) primary farmer organizations (locally called PO), unifying farmers from the same village or parish; (ii) county or sub-county level associations, usually called depot committees (DC) or area cooperative enterprises (ACE), which are small-scale producer unions consisting of several PO from the same county or sub-county. Typically, a PO is concerned with bulking individual farmers' coffee produce and delivering it to a

DC/ACE. The DC/ACE, in turn, collects the quantities bulked at the PO-level and conducts milling and other value addition activities (e.g. quality control, sorting, etc). In addition, DC/ACE may be used as a platform for organization of the VSS certification among a producer group. (In order to undergo certification despite their low individual production volumes, smallholder farmers have to unite and get involved in a certification scheme as a group.)

In practice, not all coffee produced by RPO members is sold through the DC. From the IFPRI, (2010) survey, we estimated that 47.9% of coffee produced by RPO members is, in fact, sold to local middlemen. RPO members reported to generally prefer selling their produce through the DC, mainly because it is able to offer higher prices (because of its extra value addition). However, in reality RPO face strong competition for member produce from local middlemen traders and, despite price incentives, farmers often choose to sell through middlemen. High time preferences, informal contract obligations, urgent needs for cash and competitive prices that middlemen offer are reasons given for this behavior (Latynskiy and Berger, 2014).

2.3. *Costs and Benefits of UTZ Certification*

There are several drivers that motivate coffee farmers and RPO to engage in UTZ certification. First of all, it is the price premium that they receive for selling coffee as certified. Secondly in UTZ, due to its traceability system, the price transmission and premium calculation is transparent for the producer. This transparency also strengthens producers' bargaining positions, when negotiating prices with buyers. Thirdly, with the certification farmers receive technical assistance and coaching on good agricultural practices, which has a potential to increase the quantity and quality of the produce. And fourthly, RPO willing to be group certified attract external support from NGO that assist them in achieving and maintaining certification (e.g. in case of Uganda NGO such as Solidaridad, USDAF, UDET are involved in the process.) What hinders the adoption of certification, are the related costs of initial training, internal and external audits and standard compliance. There are also information barriers, such as knowledge about the certification and associated benefits and the resistance to change among potential adopters.

2.4. *Case Study*

Our study focuses on the RPO called "Kibinge coffee farmers association" (Kibinge DC), a sub-county level farmer-owned organization from the Kibinge sub-county in the Masaka district of Central Uganda, a traditional coffee-growing area in the central part of the Lake Victoria Crescent. The area is characterized by favorable agro-climatic conditions for crop cultivation and relatively good connectedness to input and output markets (Ruecker et al., 2003). The predominant cultivation system is intensive coffee and banana (plantain) intercropping, where coffee is the main cash crop and plantain is the main staple crop. The climate in the area allows for two crop-growing seasons: (i) May to August and (ii) October to February. The agricultural system has a semi-subsistence nature. It is marked by very low levels of technology use and mostly relies on manual labor.

Kibinge DC is occupied with the marketing of robusta coffee. The DC was founded in 1995 and officially registered as a cooperative in 2008. It is currently a member of National Union of Coffee Agribusinesses and Farm Enterprises (NUCAFE), a nation-wide union. In total, the DC consolidates 46 village PO and 1,716 farming households, to whom it offers a range of services, such as training for good agricultural practices, provision of planting material, management of transportation and others (described in more detail in Latynskiy and Berger (2014)). Kibinge DC became engaged in group certification with UTZ Certified starting in 2008. The initial costs for UTZ certification in Kibinge DC were fully covered by NUCAFE and various NGO (NUCAFE, 2008; Verkaart, 2008). Under the current arrangement of UTZ certification in Kibinge, the DC (i.e. members through annual contributions and fees) have to cover only the running costs of certification, while the costs of initial investments were funded externally. Initially, 450 member farmers selected from the roughly 2,000 members of the DC at the time (some households may have several members) received initial training and technical support from an UTZ consultant (NUCAFE, 2008). Thus, at the time of our research, members of the Kibinge DC were selling both conventional and UTZ Certified coffee. The producer price premium for the certified coffee then constituted around 350 Ugandan Shillings[2] (ugx) per kg of dried green coffee beans.

3. Computational Model

We chose simulation modeling as a tool for our empirical assessment of UTZ certification. This approach had several advantages over using survey-based econometric analysis, which is commonly used for impact assessments in agricultural economics. Amongst the advantages were the lower implementation costs and earlier availability of the results. Another point was the large portfolio of experimental treatments (due to the low cost of computer-based experimentation) that could be implemented with the model, which allowed for testing different certification scenarios with respect to financing and member inclusion. Finally, simulation modeling assured researchers control over the experiment, which is problematic to achieve in the real-world experimentation.

For technical implementation of the simulation model of the RPO we used MPMAS, which is a multi-agent software package for simulating household-based economic decision-making (Schreinemachers and Berger, 2011). The purpose of this software package is identification

[2] 1US dollar = 2,154 Ugandan Shillings in 2010 (Source: www.oanda.com)

(through scenario-based analysis) of the effects of technological, environmental, policy and other changes and interventions on the studied population and the related resource pools (natural, labor, financial, etc.). MPMAS was originally constructed by Berger (2001) for the analysis of diffusion of technological innovations in Chile and has been applied since then in a number of developing countries: Uganda (Schreinemachers et al., 2007), Ghana (Wossen et al., 2014), Thailand (Schreinemachers et al., 2010) and others. The simulation models of the MPMAS framework build on the empirical and theoretical parameterization of the natural environment, populations of farm households, markets for agricultural commodities, biophysical and social interactions.

In this article we describe the application of MPMAS to Uganda using the extended version of the Overview, Design Concepts and Details (ODD) protocol (Grimm et al., 2006). The protocol extension (ODD + D, where the extra D stands for decisions) was proposed by Müller et al. (2013) and is suited for descriptions of agent-based models that include human decision-making. In our model description we use same order and titles of model structural elements as provided in Müller et al. (2013).

3.1. *Overview*

3.1.1 Purpose

The purpose of MPMAS Uganda application is the identification of development interventions that can improve the livelihoods of RPO members and the assessment of the impact of those interventions. Results of the model aim to supply policy makers with insights into the potential effects of RPO empowerment measures, thereby supporting the selection or rejection of respective interventions for practical application.

3.1.2 Entities, State Variables and Scales

There are two fundamental types of agents in MPMAS Uganda: farming household agents and an RPO agent. Household agents in the model have characteristics of real-world households, such as the number, age and sex of household members, land available, size of the coffee plantation, quantity owned of various livestock types, membership in an RPO, access to agrochemicals and certification, liquidity, own rate of time preference in coffee transactions, the annual remittances inflow and prices of products sold and services received. The RPO agent is characterized by fixed and variable costs of RPO activities as well as transactions received from RPO members (household agents). In MPMAS Uganda we implemented a one-to-one correspondence between agents and the population that is being modeled, which means that 1,716 real-world members of the Kibinge DC are represented by 1,716 household agents in the model, and the DC itself is represented in MPMAS Uganda by the RPO agent.

The landscape is represented by the topographic, physical and chemical properties of land possessed by household agents. Agents land holdings are divided as pixels each equal to quarter of an acre. Each pixel has the following attributes: (i) elevation, slope and flow accumulation (topographic attributes), (ii) percentage of sand, clay and silt separates in the unit of soil and soil organic matter (physical attributes) and (iii) amounts of nitrogen, potassium, phosphorus, calcium and sodium and soil acidity (chemical attributes).

The model runs in yearly time steps over a period of 1-20 years. Agent decisions on investments, production, marketing and consumption are taken once per simulation period (year).

3.1.3 Process Overview and Scheduling

The simulation cycle of MPMAS Uganda is schematically displayed on the flow chart in Figure 1. After MPMAS is initialized, the evolution of a large number of variables and processes is simulated over time (such as soil properties, household characteristics, market prices, etc.). An MPMAS Uganda simulation period starts with the calculation of agent expectations for future prices and crop yields. Throughout the simulation period, given their resource supply, natural environment and expectations agents take various decisions. Based on these decisions MPMAS updates agent and landscape characteristics, simulates natural processes and implements temporal carry-over of assets within and between simulation periods. As such, the decisions on crop management influence soil fertility, which in turn determines future yields. These then define future plot management. This loop of human-environment interactions and feedbacks is simulated in MPMAS Uganda by the biophysical simulator, Tropical Soil Productivity Calculator (TSPC) developed by Aune and Massave (1998), which is internally coupled with the MPMAS software[3].

3.2. *Design Concepts*

3.2.1 Theoretical and Empirical Background

The agent decision in MPMAS Uganda is simulated assuming *bounded rationality,* which means that agent behavior is rational, but limited by the agent’s information, cognitive and mental constraints. For simulating household consumption preferences, we extended and adapted the methodology of Schreinemachers et al. (2007), which in turn was based on theoretical concepts of Leser (1963) and Deaton and Muelbauer (1980).

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[3] The integration of TSPC is explained in Schreinemachers et al. (2007).

The integrated simulator of crop yields and simulation of soil property dynamics, TSPC, models crop growth based on the on Mitscherlich's relative yield theory. It was specifically parameterized and calibrated for Ugandan agro-ecological conditions by its developer J. Aune within the work of Schreinemachers et al. (2007). The estimated partial production functions for crop yields with respect to labor input were specified as a Cobb-Douglas function in logarithmic form, following the Cobb-Douglas theory of production.

Both the interventions that MPMAS Uganda was developed to test and the design of the simulation experiments were informed by participatory research in Uganda (Latynskiy and Berger, 2014).

3.2.2 Individual Decision-making

Decision-making of household agents is modeled in MPMAS using the mathematical programming (MP) methodology, which tackles the problem of constrained optimization. The objective function of each agent is its expected household utility, which has to be maximized subject to a set of constraints, specified in the form of equations or inequalities. The optimization problems in MPMAS Uganda are formulated in a way that their results describe the decision-making that actually takes place in the real world (i.e. positive modeling), rather than to prescribe the best use of available household resources (i.e. normative modeling). This is achieved by incorporation of behavioral constraints and decision rules that define household behavior as following bounded rationality (see for more details Schreinemachers and Berger, 2006). The objective function of each household agent is its expected household utility, which has to be maximized subject to a set of individual constraints, specified in the form of equations or inequalities. Table 1 provides a concise[4] representation of an optimization problem of a household agent implemented in the MPMAS Uganda application.

The decision-making of household agents in MPMAS Uganda is split into four sequential steps: investment, production, marketing and consumption. Such segmentation of decision-making is required to reflect the resource allocation and timing of activities. (E.g. liquid assets that a farmer uses for a long-term investment at the start of a cropping season cannot be used in production activities throughout the season.) The steps are implemented by recursive solutions of agent MP matrices: each decision step involves the optimization of a particular MP problem and transferring certain parts of the solution vector to the MP matrix of a next step. Table 2 describes the respective four stages of decision-making. Each agent MP is specified such that when taking an investment decision, an agent already plans for production, marketing and consumption; when deciding upon

[4] The full MP matrix of the MPMAS Uganda application contains 2,785 activities and 544 constraints.

production, an agent already plans for marketing and consumption; and so on. The MP matrix in Table 1 integrates activities related to household investment, production, marketing and consumption behavior. Implemented constraints reflect household resource limitations, time preferences, nutrient demand of household members, crop rotations, production factor requirements, credit obligations, etc. MPMAS makes the decision problem agent-specific by changing right and left hand side coefficients and fixing solutions for certain columns in the respective standard format of the tableau.

3.2.3 Learning

Individual and collective learning is not implemented in this study.

3.2.4 Individual Sensing

MPMAS implements imperfect sensing and foresight: Household agents do not have knowledge about exact crop yields in the upcoming harvest; they know only the yields they received from their plots in the past. The same is true for the RPO price formation mechanism: the agents only have the hindsight knowledge of prices for products and services of the RPO.

3.2.5 Individual Prediction

Household agents have adaptive expectations, which imply that agent expectations about what will happen in the future are exclusively based on what has happened in the past. In this case, the expected values (EV) of the current period are calculated from the actual (AV) and expected values of the preceding period. Actual values of the preceding year are adjusted with the λ-share of the difference between expected and actual values of the preceding period:

$$EV_n = EV_{n-1} + \lambda * (EV_{n-1} - AV_{n-1}) \quad (1)$$

Yield expectations are formed by crop and by plot, i.e. an agent would form the same expectation for yield trend for the same crop on the same plot even when grown with a different practice.

3.2.6 Interaction

Household agents interact with the landscape (represented by properties of their plots) through cyclical crop management – crop yield – soil property updates. Household agents also interact directly with the RPO agent and indirectly with each other through the RPO (mechanism explained in the next paragraph).

3.2.7 Collectives

RPO were introduced to MPMAS modeling framework as a specific agent type in addition to and different from farm household agents. The decision-making and activity of this agent is also simulated through solving an MP matrix for the RPO agent. The objective function of RPO agent is the expected profit of the organization, which has to be maximized subject to a set of constraints. Table 3 shows the MP tableau (concise form) describing the optimization problem of the RPO agent.

The RPO decision is simulated between marketing and consumption stages of household agent decisions (Table 3). Since RPO work with farm households in many ways, the RPO agent also interacts with farm household agents. Farm agents "send" to RPOs their production, membership fees and inquiries for inputs, which serve as exogenous variables for the decision-making module of the RPO agent. The RPO agent in turn "feeds" the sales prices and per unit costs back to farm agents, which influences their decision-making. Figure 2 schematically displays the interaction process between the two agent types.

3.2.8 Heterogeneity

All household agents differ from each other according to their household characteristics, resource endowments and land properties. The full agent population (1,716 households) was generated from the sample fraction covered by IFPRI (2010) survey (71 households) following the approach of Berger and Schreinemachers (2006). In order to do this, an empirical multivariate distribution of household characteristics in the survey sample was first captured by the estimation of a copula function. Then the required amount of agent profiles was sampled from this empirical copula. Calculated statistics from Table 4 show the characteristics of the generated population of household agents.

3.2.9 Stochasticity

The initial characteristics of household agents are sampled from the empirical distribution function. Demographic processes are simulated based on empirical mortality and fertility rates. Genders of newborn household members and livestock units are randomly allocated. Initially certified RPO members (household agents) are also randomly drawn.

3.2.10 Observation

As household-level indicators for analysis in this study, we use simulated sales revenues and incomes of household agents, as well as simulated added values of certification. At the organization level we use amount of coffee sold through the RPO agent (both conventional and certified), operating profit of the RPO agent and whether or not the certification was sustained.

3.3. *Details*

3.3.1 Implementation Details

The model is implemented in MPMAS software package, available as freeware. The software itself, the manual and technical documentation are available online at the software website[5]. The software is written in C++ and constitutes a single executable file. For solving agent MP-problems, MPMAS uses either the IBM Optimization Subroutine Library (IBM OSL) or the COIN-OR SYMPHONY solver.

Input files of MPMAS Uganda are organized in Excel workbooks. An Excel add-in must be installed in order to set up simulation scenarios and convert workbooks into an ASCII file format for processing by the MPMAS software. Input files for the MPMAS Uganda application, the Excel add-in and the technical documentation describing implementations of modules and MP-problems are also available for download from the MPMAS website.

3.3.2 Initialization

Initial agent expectations on prices and costs in the MPMAS Uganda application were set equal to the prices and costs recorded by IFPRI (2010). Initial yield expectations, were first manually calculated using TSPC equations. These calculations were performed for classes of soils. The transition from soil-specific to agent-specific (due to the uniqueness of agent soil properties) expectations is performed by MPMAS, which recursively updates the initial expectations during model spin-up periods that precede normal simulation periods. During spin-up periods, only the agent expectations are updated, while agent physical and financial assets, soil properties and population demography remain constant. Several spin-up periods are needed to form stable initial yield expectations, which are agent- and soil- specific.

[5] mp-mas.uni-hohenheim.de

3.3.3 Input Data

Parameterization of the MPMAS Uganda application was based on various datasets: project surveys, publically available nation-wide population census and others. Table 5 characterizes the parameterization of MPMAS Uganda with respect to datasets and sources of information used.

3.3.4 Sub-models

Because of the necessity to adapt MPMAS for different study contexts, the structure of the MPMAS software is modular (i.e. model components and features can be activated depending on the requirements of the particular research). Such a structure makes MPMAS flexible and adaptive with regards to additional extensions. The modules are either integrated or externally coupled. MPMAS Uganda uses the integrated crop growth (TSPC), perennial crops, livestock, consumption and RPO modules of the MPMAS software. Detailed description of modules used in this application and their adaptations can be found in Latynskiy (2014).

4. Model validation

4.1. *Methodology*

Generally, there are five types of validity that economic simulation studies must take into account (Richiardi et al., 2006). All together they contribute to the overall model validity. These five parts are the validities of: (1) underlying theories, (2) model representation of the theories, (3) computer software used for simulation, (4) incorporated indicators concerning related unmeasured properties and (5) simulated results with respect to empirically occurring facts.

The MPMAS software and its application used in this study were revised with respect to each of the listed validity types. The validation of MPMAS Uganda concerning the first four (from the list above) is reported and discussed in Latynskiy (2014). In this article we provide statistics assessed for the empirical validation of the MPMAS Uganda application.

The empirical validation was carried out in a commonly practiced manner among the agent-based modelers (Fagiolo et al., 2007; Windrum et al., 2007): model outputs were compared with the stylized facts about the respective real-world system (in our case the agricultural system in the study area). As a benchmark for model calibration and validation we applied mean quantities of household crop and livestock production, which we estimated for our study area from IFPRI (2010) project survey. In order to check the robustness of the model with respect to random events that occurred during agent population and landscape generation, validation was repeated using ten alternative landscapes and populations. The goal that we pursued when calibrating MPMAS

Uganda for the chosen benchmark was a close representation of coffee production, since high precision in modeling coffee production is desirable for the particular research purpose. At the same time, errors for other crops were kept to an acceptable level whenever possible.

4.2. *Results of empirical validation*

Table 6 reports the model prediction errors of the ten model simulations conducted with these ten alternative generated initial model conditions. Prediction errors in this table are expressed by the absolute value percentage difference between average household agent production simulated by the model and household production estimated from the survey. For ruminant livestock (cattle and goats), the amounts of livestock kept on the farm were compared, while amounts sold and used for home consumption were used for other livestock and crops amounts in the comparison. From Table 6 it is evident that the model replicates production of crops fairly accurately, with average errors lying below 27% and the maximum below 37%. Coffee production deviates from the benchmark by only 0.88%, simulated production volumes of maize and plantain lay within 2.5% on average. The maximum error from the benchmark for coffee from the ten simulations was recorded at 2.12%. In the case of livestock, the model average prediction errors lie within 15.6% and the maximum within 21.48%, which is an acceptable result.

After the aggregated amount of production, we looked on the coffee yields simulated by the model and compared them with observed survey yields. Table 7 presents results of the comparison. (Unfortunately, the absence of crop level data in the project survey for other model crops meant it was not possible to conduct empirical validation of yields for those crops.) The model yield statistics in Table 7 are reported as aggregate statistics for the ten test model runs conducted with different random populations and landscapes. As can be seen from Table 7, the model reproduces the mean yield (1317.0 kg per ha per annum in the survey and 1259.5 in the model) rather closely. However, there is a higher variance in yields of the survey population (standard deviation of 1153.5 kg per ha per annum) than in the model (645.4). The simulated distribution of the achieved coffee yields is close to the observed distribution in some parts (10th, 25th, 75th percentiles), while deviating substantially for other parts (median, 90th percentile).

We also compared distributions of production amounts of individual households. As an example of this exercise, Figure 3 compares respective distributions for the most commonly grown by households in the study area according to IFPRI (2010). The model results are again reported as aggregates of the ten test model runs. Like in the case of the aggregate production statistics (Table 6), one can again observe a close match of model results with the reference survey data for coffee. As can be seen from Figure 3, however, for some other crops parts of the simulated distributions differ from the survey distributions. For example, the model underestimates the number of smaller producers and overestimates the number of middle-size producers for plantains (Figure 3). Such errors in density functions may smooth out on the aggregate level, like in cases of coffee, maize and plantain (see Table 6). The conducted comparisons of distribution functions suggest that, on a household level, the accuracy of the model decreases for some farm activities. Therefore, one may want to avoid using this model for making precise point predictions for particular farm households. In any case, this study is not intended to make such predictions: rather, it is meant to assess the directions and magnitudes of various treatments on the group of households, producing patterns and simulating processes for meso-level analysis (see next chapter). Nevertheless, such aggregate-level analyses are made by taking into account the heterogeneity of individual farm households captured by agent-based formulation of the MPMAS Uganda model.

Finally, we calculated goodness-of-fit statistics and Nash-Sutcliffe model efficiency (NSE), which are commonly established assessment measures of how well the model results fit the set of empirical observations. In case of this work, these measures were applied to validate the model results for average farm production: observed and simulated production volumes of different farm outputs were compared (again using ten test agent populations and landscapes analogously). In order to make different outputs comparable, we expressed them in their monetary value. Table 8 reports calculations of goodness-of-fit and NSE, while Figure 4 graphically shows the derivation of a regression line and indicates point estimates for different farm activities in relation to it. Results presented at Table 8 and Figure 4 show that the constructed model has a good fit and efficiency when simulating the outputs of farming system on the level of population averages.

5. Simulation experiments and results

5.1. *Scenarios*

For the assessment of UTZ certification we conducted 96 simulation experiments (scenarios) that reflect different situations and set-ups of UTZ certification, plus a baseline scenario with no certification. The scenarios differ by the costs that the RPO agent bears. In scenarios with prefix *nc_*, the RPO has no certification-related cost, which means that these costs are covered by external sources (e.g. government funding, NGO etc.). In scenarios with prefix *rc_*, the RPO agent covers only the running costs of certification, while the costs of initial investments are funded externally. In all other scenarios, the RPO has to repay the initial investment as well, with varying interests rates: in *zi_*, with a zero interest rate; in *fi_*, with a risk-free interest rate[6]; and in *mi_*, with a market

[6] Equals to 8.5% (nominal) in 2010 for Uganda (estimated from World Bank, 2014)

interest rate[7]. Furthermore, the scenarios with initial investment repayment vary by the length of reinvestment period (i.e. how often the initial investment has to be repeated). The reinvestment period length is indicated in the scenario name by *rp*<length>. The share of RPO members included in the certification program also varies (*mempct*<percent of members included>), as does the share of coffee produce that members are permitted to certify (*prodpct*<percent of individual produce allowed for certification>). (According to Potts et al. (2014), due to the oversupply of standard-compliant coffee, typically not all the coffee produced in accordance to VSS, can be sold as certified.) The current certification scheme at Kibinge DC is then represented by scenarios where only the running costs have to be covered (i.e. prefix *rc_*) and where 22% of all members are certified from the beginning (i.e. *mempct22*).

The MPMAS Uganda simulation model includes only those agents whose real-world prototypes are current RPO members. Hence, membership in the RPO is fixed in the simulation model, i.e. the RPO agent may neither attract new members, nor lose existing members. Across all the simulation scenarios, land ownership and sizes of coffee plantations are fixed over the runtime. Agents can change their management practices (input and labor intensity, crop mixes of food crops) and replant coffee plantations, but cannot expand or reduce the land ownership or parcels used for coffee growing. Consumption preferences of agents remain constant. Production costs and market prices for all products except coffee are constant at the initial levels (estimated from IFPRI, 2010). Farm-gate coffee prices are endogenously simulated by the implemented RPO-module, depending on the turnover and certification costs of RPO. For agent expectations with regard to coffee prices, the λ-parameter of 0.5 is applied. For agent yield expectations, the λ-parameter for yields is set to 1: agents expect yields of the preceding period. All simulation runs were performed with the same initial population and random seed. In the case of all scenarios, the simulation model was run for 15 normal simulation periods, preceded by three spin-up periods and one initialization period[8] during which agents formed their expectations and adjusted the initial resource allocations.

5.2. *Results*

The results of the 96 simulation runs for UTZ certification are provided in Table 9. The table reports simulated added value of certification, changes (as compared to the baseline scenario with no certification) in household agent income and RPO agent profit caused by certification simulation and sustainability of the arrangement. The added values are reported as averages over all household agents selling certified coffee and over 15 simulation periods. The same aggregation is done for the

[7] Equals to 19.2% (nominal) in 2010 for Uganda (estimated from World Bank, 2014)

[8] These four extra periods at the start of the simulations are "technical" and serve to correctly initialize the model. Therefore, their results were not considered in the assessment.

changes in household agent income. The reported changes in the RPO agent's profits are also average values over 15 simulation periods. The sustainability is positive when the certification is sustained over 15 simulation periods and negative if it was discontinued during this time (due to the negative profitability).

The experiments suggest sustainability and, therefore, positive profitability in all set-ups in which the RPO agent does not have to repay the initial investment (*nc_* and *rc_* scenarios). In scenarios with the repayment of investment costs (*zi_*, *fi_* and *mi_*), negative profitability (i.e. non-sustainable certification) occurs: these are the scenarios in which agents are only able to certify a small share of their produce (e.g. *zi_rp5_mempct22_prodpct25*, *zi_rp5_mempct50_prodpct25*, *fi_rp5_mempct22_prodpct25*, etc.).

Let us review more closely the scenarios reflecting the current financing of certification in Kibinge DC, where only the running costs have to be covered by the RPO agent and its members (*rc_* scenarios). Figure 5 shows coffee sales of the RPO agent in physical terms. A comparison of the results from scenarios *rc_mempct22_prodpct25*, *rc_mempct22_prodpct50*, *rc_mempct22_prodpct75* and *rc_mempct22_prodpct100* (current share of members involved; 25%, 75%, 50% or 100% of produce can be certified) shows that improving the share of certified coffee in the total amount of individual household agents' produce also has an amplifying effect on the total amount of sales carried out through the RPO-channel. Comparing the outcomes of scenarios *rc_mempct22_prodpct50*, *rc_mempct50_prodpct50* and *rc_mempct100_prodpct50* (50% of produce certified; current, half or full share of population involved) in Figure 5 shows that including more members in the certification program is also simulated to increase the sales of the RPO agent in physical terms (despite the increasing running costs). In general, UTZ certification is simulated to have a high potential for attracting members to the RPO selling channel: in the most unrestricted scenario (*rc_mempct100_prodpct100*) the turnover of the RPO agent rises by 135.1% in comparison to the baseline (*b*). The results also demonstrate that household agents prefer to sell their coffee through the RPO agent as certified produce. Such a preference is caused by the added value of coffee from certification (Table 9). In the scenarios reflecting the current financing of certification program (*rc_* scenarios), this value is relatively high (222 – 309 ugx per kg of green coffee, depending on the scenario) compared to the price of conventional coffee (the price in the baseline scenario is 2,486 ugx per kg). Therefore, agents prefer to bear the certification-related costs, which in this case are the individual and organizational running costs of the certification. Simulated added values (Table 9) increase with larger member inclusion and improvement of certified coffee share as well.

Figure 6 displays the income effects caused by the certification schemes with current membership levels (22% of members). This figure compares mean per capita incomes simulated in scenarios with current share of members involved and 25%, 75%, 50% or 100% of produce allowed to be certified with a baseline. The simulation experiments show a moderate aggregate impact of the current certification program on simulated per capita incomes of model agents. Even if agents are able to certify 100% of their coffee (*rc_mempct22_prodpct100*), the mean income lies at a rather modest 4.0% above the baseline. If the share of certified coffee falls to 50% (*rc_mempct22_prodpct50*), then the mean income exceeds the baseline by only 1.6%. However, the simulated potential impact of certification is much higher. The dotted line on Figure 6 illustrates the development of per capita income when all members are involved in certification and all coffee produce is able to qualify for certification (*rc_mempct100_prodpct100*). In this case, the mean impact of certification constitutes 14.5% of the baseline per capita income. Figure 7 disaggregates the potential impact of certification in terms of per capita income. This figure displays simulated income changes of all household agents. From the figure it can be seen that the majority of agents benefit from the certification. The positive income effect is significant across all income sizes. The fitted lowess line suggests a larger relative income change for the agents with the lowest baseline income, and a smaller change for the agents with highest baseline income.

We also calculated the cost efficiency based on the results that the simulation model produced, using the real market interest rate for borrowed capital[9]. As key indicators of efficiency, we use equivalent annual net benefit (EANB), benefit-cost ratio (BCR) and economic rate of return (ERR). Table 10 reports the calculated efficiency indicators for six of the tested implementations of the certification program. All scenarios in the table refer to the situation in which the initial investment into certification has to be repeated every five years. In scenario set-ups of ongoing certification, agents have to finance only the running costs of certification, while investment costs are funded externally. In scenarios with full self-financing, agents participating in certification also have to repay the initial investment financed by means of a fixed interest rate loan provided with market interest. Both ongoing and self-financing set-ups were simulated with the current member inclusion into the certification program (22% of agents) and with the alternative “improved” inclusion (50% of agents). In addition, for both programs the maximum potential effect of certification was simulated by running the model with all agents certified at the beginning of simulation. Also, maximum potential scenarios have no restriction on the amount of produce that agents can certify, while in other scenarios in Table 10 each agent can certify a maximum of 50% of its produce.

[9] Equals to 11.48% in 2010 for Uganda (estimated from World Bank, 2014)

6. Discussion

6.1. *Interpretation of results*

Our simulation results suggest that the ongoing program of UTZ certification in the case study of Ugandan RPO has a positive impact on participating farmers. In the scenarios with current member inclusion, the certification resulted in positive added value that constituted, depending on the scenario around 8.9 – 12.4% of the price for uncertified coffee. In terms of income of RPO members, the ongoing program is expected to result in a 2% improvement when farmers are able to certify up to 50% of their produce, and a 4.8% improvement when up to 100% of produce. Engagement in certification substantially increases the profit of the RPO (which is passed to farmers through better prices), up to 87%, if participating members are able to certify everything. By improving the profitability of RPO, the certification also creates a spillover effect increasing the amounts sold through the RPO (the RPO-channel gets more attractive, because of extra value addition possible), which in turn improves prices for other (non-certifying) members.

However, the results also show that if the ongoing program is later converted to full self-financing, in some scenarios it may turn unprofitable and be discontinued. Our simulations show that in order to be sustainable and continue creating a positive impact, the program must ensure the inclusion of a higher share of members. Otherwise, reinvestments have to be funded externally. The full self-financing, however, would likely require breaching the RPO liquidity constraint (for example, by providing credit from development aid) in order to initiate the certification process, given the relatively high costs of initial investment for UTZ group (Verkaart, 2008).

As our cost-efficiency analysis shows (Table 10), the external funding of the ongoing program is an efficient public investment (i.e. the simulated benefit is larger than the estimated spending). As Table 10 also suggests, there is potential for improving the ongoing certification program (assuming that 50% of the coffee could be certified). The simulated potential net effect of the ongoing certification is 7.7 times higher than the simulated current effect. Nevertheless, even in the most optimistic scenario (all costs covered externally, all members included and no non-compliant coffee), the income effect of UTZ certification is still only 14.7%, while in more realistic scenarios the income effect lies below 10%. This means that certification alone cannot be viewed as a “silver bullet” for improving livelihoods in the study area. The achievement of sustainable growth would likely require addressing not only marketing, but also production constraints, such as low use of improved varieties, low intensity of fertilizer application and lack of knowledge about appropriate agricultural practices (Asenso-Okyere and Jemaneh, 2012; Hazell, 2005).

6.2. *Model Limitations*

Since the simulation model was parameterized based on empirical data from a particular subcounty-level RPO, there is a case study bias in the results. Therefore, one should consider the specifics of the case study before making any generalizations for other RPO in Uganda. The first point to consider is that Kibinge DC, with its 2,000 members, is a relatively large organization: according to our estimations from IFPRI (2010) survey, DC/ACE in Uganda have 1006 members on average and 550 on median. In smaller organizations, UTZ group certifications are expected to have lower cost efficiency, since they would have larger costs per member. Secondly, compared to other RPO in the country, Kibinge DC's business operations are well organized (Dejene-Aredo et al., 2009). The situation may differ for RPO with weaker infrastructure and management capacity.

The percent of the standard-compliant coffee that household agents could produce is an exogenous variable in our simulations. The information on the actual shares of compliant and defected produce, as well as the causes of the defects, was not captured in the datasets we worked with. Yet, it would be interesting to model how such defects could be minimized and how the adoption of sustainable practices could be successfully spread across the population.

The project survey (IFPRI, 2010) covered only the households that were RPO members at the time of the survey, while data from other producers were not collected. Consequently, the simulation model did not include any non-member agents and agent membership in the RPO was fixed during simulation. Therefore, in the current implementation of the model, it is not possible to simulate potential spillover effects of certification attracting new members.

7. Conclusion and outlook

This article showed that multi-agent modeling can be used for provision of high-resolution quantitative data for assessment of VSS certification, which is up to now scarce. The model is useful in assessing the alternative scenarios and possible ways of improving the VSS arrangements. With regard to UTZ certification for coffee carried out by RPO in Uganda, the model results showed that the certification generally provides significant and positive impacts on participating households and, also, creates spillover effects on other members of the RPO. However, in certain circumstances the certification could be discontinued after the dis-involvement of external funding, due to high costs for the RPO. Lowering costs per participant of group certification schemes by involving larger groups of farmers into certification from the beginning and increasing the share of standard-compliant coffee are expected to improve the probability of certification being sustained over longer time periods. The results have shown that public investments in financing UTZ certification through RPO in Uganda could be viewed as efficient spending.

Since we found that certification alone has a rather modest effect in terms of livelihood improvement, the next step of our research is using the developed model to identify packages that could support the commercialization of smallholders along with certification (such as input credits, improved varieties, etc). Another proximate use of the model is the assessment of other prominent initiatives of VSS certification for coffee (i.e. FairTrade, Organic, etc), once the reliable cost data for coffee is acquired.

In order to have a holistic picture of world-wide impacts of UTZ and other VSS certifications, it is necessary to conduct a consistent cross-county comparison. This requires impact assessments to be carried out in other country settings. The results communicated in this article show that such assessments must consider the cost associated with establishing a certification program and complying with its standards.

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Tables and Figures

Table 1: Concise representation of MP tableau of household agents

	Sell output	Purchase prod. inputs	Purchase cons. products	Self-consumption	Credit	Hire labor	Make investments	Grow crops	Raise animals	Transfer activities	Budgeting	Sell future output		
Maximize	*P*	-*P*		*P*	-*P*	-*P*	-*P*	-*P*	-*P*			-*P*		
Land							*A*			1			=	*R*
Labor						-1		*A*	*A*				<=	*R*
Investments							-*A*	*A*	*A*				<=	*R*
Input		-1						*A*	*A*				<=	0
Output	1			1				-*A*	-*A*				<=	0
Future output								-*A*	-*A*			1	<=	0
Feed								-*A*	*A*				<=	0
Manure								*A*	-*A*				<=	0
Land balance								1	*A*	-*A*			<=	0
Income	*P*	-*P*		*P*	-*P*	-*P*	-*P*	-*P*	-*P*		-1		=	0
Liquidity		*P*			-1	*P*	*P*	*P*	*P*				<=	*R*
Consumption model			*A*	*A*							-*A*		=	0

P - vector of market prices and costs; *R* - agent-specific right hand side values;
A - agent-specific technical coefficients

Table 2: Stages of household decision-making in MPMAS

Stage / Characteristic	**Investment**	**Production**	**Marekting**	**Consumption**
Timing	beginning of the period	beginning of the period	end of the period	end of the period
Yields	expected in future	expected in current period	actual	actual
Resource supply	expected in future	expected in current period	actual	actual
Prices	expected in future	expected in current period	expected in current period	actual
Fixed decision variables	none	none	land and input use, production	land and input use, production, sales of certain crops

Table 3: Concise representation of MP tableau of RPO agent

	Collect membership fees	Purchase inputs	Distribute inputs	Collect produce (conventional)	Collect produce (certified)	Transport produce (conventional)	Transport produce	Process produce (conventional)	Process produce (certified)	Sell products (conventional)	Sell products (certified)	Pay running costs (fixed part)	Pay certification cost (fixed part)	Pay producer motivation payments		
Maximize	*P*	-*P*	-*P*	-*P*	-*P*	-*P*	-*P*	-*P*	-*P*	*P*	*P*	-*P*	-*P*	-*P*		
Membership fees	-1														<=	*R*
Input inquiries			1												=	*R*
Purchased inputs		-1	1												<=	0
Raw produce (conventional)				1											<=	*R*
Raw produce (certified)					1										<=	*R*
Collected produce (conv.)				-*A*		1									<=	0
Collected produce (certified)					-*A*		1								<=	0
Transported produce (conv.)						-*A*		1							<=	0
Transported produce (certified)							-*A*		1						<=	0
Processed product (conv.)								-*A*		1					<=	0
Processed product (certified)									-*A*		1				<=	0
Fixed costs												1			=	*R*
Certification cost													1		=	*R*
Motivation payments														1	=	*R*

P - vector of market prices and costs; *R* - right hand side values; *A* - technical coefficients

Table 4: Characteristics of agent population

Characteristic	**Unit**	**Mean**	**Median**	**St.dev.**	**10%**	**25%**	**75%**	**90%**
Available land	ha	2.46	2.02	1.66	0.81	1.39	3.16	4.95
Household size	person	6.8	7.0	2.5	4.0	5.0	8.9	10.0
Household size	male adult equivalent	5.1	5.0	1.9	2.7	3.7	6.5	7.6
Labor/land ratio	person per ha	3.84	3.32	2.67	1.28	2.04	4.92	6.78
Coffee plantation	ha	1.18	0.89	0.93	0.30	0.50	1.61	2.34
Cattle owned	head	2.4	2.0	4.4	0.0	0.0	3.0	4.8
Goats owned	head	2.4	1.0	3.5	0.0	0.0	3.5	6.0
Chicken owned	head	11.6	0.3	19.1	0.0	0.0	18.3	34.8
Pigs owned	head	1.2	0.3	1.6	0.0	0.0	2.0	3.0
Livestock stocking rate	FAO unit per ha	1.00	0.59	1.54	0.07	0.25	1.16	2.27

Table 5: Datasets

Model parameters	Estimation	Dataset
Soil properties	Rhew et al. (2004)	Ruecker (2003)
Crop growth model	Schreinemachers et al.(2007)	expert knowledge, literature
Land ownership	Authors	IFPRI (2010)
Household assets	Authors	IFPRI (2010)
Labor production function (coffee)	Authors	IFPRI (2010)
Labor production function (staples)	Schreinemachers et al.(2007)	IFPRI (2001)
Consumption preferences	Authors	IFPRI (2010), UNPS (2010)
Livestock	Authors	UNPS (2010), UNLC (2008), IFPRI (2010), literature, expert knowledge
Population and demography	Authors	UDHS (2007), IFPRI (2010), World Bank (2014)
RPO model	Authors	IFPRI (2010), participatory research
Certification costs	Authors	NUCAFE (2008)

Table 6: Model prediction errors. Absoulte value percentage difference

	Crops							
	Bean	Cassava	Coffee	Groundnut	Maize	Plantain	Sorghum	Sweet potato
Average error	26.93	19.34	0.88	14.60	1.65	2.17	16.90	16.05
Maximum error	29.08	33.76	2.12	23.83	3.80	4.64	36.00	22.61

	Livestock			
	Cattle	Chicken	Goats	Pigs
Average error	15.60	4.93	12.73	4.81
Maximum error	18.60	11.31	21.48	8.49

Table 7: Validation of coffee yields

	Mean	**Median**	**Stdev**	**10%**	**25%**	**75%**	**90%**
Survey	1317	953.7	1153.5	326.3	583.8	1621.6	2918.9
Model	1259.5	1419.5	1419.5	412.2	574.1	1621.9	1672.7

Yields of survey population are estimated from IFPRI (2010)

Table 8: Model fit and efficiency

	Slope coef.	**R-squared**	**NSE**
Average	1.0053	0.9982	0.9981
Worst	1.0218	0.9976	0.9962

Table 9: UTZ Certification. Simulation results

Scenario code	Added value*, ugx/kg	Δ** Household income, %	Δ RPO profit, %	Arrangement sustainability
nc_mempct22_prodpct25	331	1.33	31.55	yes
nc_mempct22_prodpct50	331	2.25	37.08	yes
nc_mempct22_prodpct75	331	3.45	69.80	yes
nc_mempct22_prodpct100	331	4.69	85.82	yes
nc_mempct50_prodpct25	331	2.20	49.27	yes
nc_mempct50_prodpct50	331	4.57	86.74	yes
nc_mempct50_prodpct75	331	6.26	100.90	yes
nc_mempct50_prodpct100	331	8.13	114.58	yes
nc_mempct100_prodpct25	331	4.24	86.19	yes
nc_mempct100_prodpct50	331	7.42	115.06	yes
nc_mempct100_prodpct75	331	11.04	140.93	yes
nc_mempct100_prodpct100	331	14.73	162.31	yes
rc_mempct22_prodpct25	**222**	**0.84**	**17.59**	**yes**
rc_mempct22_prodpct50	**284**	**1.99**	**35.33**	**yes**
rc_mempct22_prodpct75	**300**	**3.37**	**62.32**	**yes**
rc_mempct22_prodpct100	**309**	**4.79**	**86.97**	**yes**
rc_mempct50_prodpct25	256	2.24	45.42	yes
rc_mempct50_prodpct50	292	4.57	85.06	yes
rc_mempct50_prodpct75	305	6.24	99.84	yes
rc_mempct50_prodpct100	312	7.93	113.41	yes
rc_mempct100_prodpct25	261	3.91	83.73	yes
rc_mempct100_prodpct50	295	7.07	109.91	yes
rc_mempct100_prodpct75	308	10.70	135.78	yes
rc_mempct100_prodpct100	314	14.54	160.60	yes
zi_rp5_mempct22_prodpct25	N/A	-0.01	N/A	no
zi_rp5_mempct22_prodpct50	189	1.56	29.94	yes
zi_rp5_mempct22_prodpct75	240	2.43	40.89	yes
zi_rp5_mempct22_prodpct100	266	4.21	83.73	yes
zi_rp5_mempct50_prodpct25	N/A	0.42	N/A	no
zi_rp5_mempct50_prodpct50	233	3.77	80.17	yes
zi_rp5_mempct50_prodpct75	267	5.38	93.03	yes
zi_rp5_mempct50_prodpct100	284	7.18	107.12	yes
zi_rp5_mempct100_prodpct25	180	2.98	68.16	yes
zi_rp5_mempct100_prodpct50	251	6.01	97.46	yes
zi_rp5_mempct100_prodpct75	278	10.14	127.87	yes
zi_rp5_mempct100_prodpct100	292	14.03	154.63	yes
zi_rp10_mempct22_prodpct25	107	0.68	9.96	yes
zi_rp10_mempct22_prodpct50	249	1.70	34.32	yes
zi_rp10_mempct22_prodpct75	277	2.84	46.83	yes
zi_rp10_mempct22_prodpct100	292	4.40	85.33	yes
zi_rp10_mempct50_prodpct25	206	1.61	36.15	yes
zi_rp10_mempct50_prodpct50	268	3.98	83.22	yes
zi_rp10_mempct50_prodpct75	289	5.68	96.56	yes
zi_rp10_mempct50_prodpct100	301	7.81	111.83	yes
zi_rp10_mempct100_prodpct25	227	3.60	80.59	yes
zi_rp10_mempct100_prodpct50	277	6.81	104.76	yes
zi_rp10_mempct100_prodpct75	296	10.15	131.25	yes
zi_rp10_mempct100_prodpct100	305	14.29	157.91	yes
fi_rp5_mempct22_prodpct25	N/A	0.08	N/A	no
fi_rp5_mempct22_prodpct50	148	1.34	25.75	yes
fi_rp5_mempct22_prodpct75	221	2.24	38.10	yes
fi_rp5_mempct22_prodpct100	252	4.04	82.16	yes
fi_rp5_mempct50_prodpct25	N/A	-0.11	N/A	no
fi_rp5_mempct50_prodpct50	216	3.65	76.83	yes
fi_rp5_mempct50_prodpct75	255	5.38	90.47	yes

fi_rp5_mempct50_prodpct100	275	7.30	105.91	yes
fi_rp5_mempct100_prodpct25	136	1.67	34.29	yes
fi_rp5_mempct100_prodpct50	238	6.17	95.80	yes
fi_rp5_mempct100_prodpct75	270	9.77	126.23	yes
fi_rp5_mempct100_prodpct100	286	13.71	154.06	yes
fi_rp10_mempct22_prodpct25	N/A	0.18	N/A	no
fi_rp10_mempct22_prodpct50	222	1.58	31.82	yes
fi_rp10_mempct22_prodpct75	260	2.72	43.04	yes
fi_rp10_mempct22_prodpct100	280	4.05	84.20	yes
fi_rp10_mempct50_prodpct25	147	0.83	18.91	yes
fi_rp10_mempct50_prodpct50	252	3.94	80.71	yes
fi_rp10_mempct50_prodpct75	280	5.78	96.71	yes
fi_rp10_mempct50_prodpct100	293	7.50	109.44	yes
fi_rp10_mempct100_prodpct25	205	3.18	75.76	yes
fi_rp10_mempct100_prodpct50	265	6.29	101.45	yes
fi_rp10_mempct100_prodpct75	288	10.14	128.87	yes
fi_rp10_mempct100_prodpct100	299	14.30	156.87	yes
mi_rp5_mempct22_prodpct25	N/A	-0.05	N/A	no
mi_rp5_mempct22_prodpct50	N/A	0.05	N/A	no
mi_rp5_mempct22_prodpct75	192	2.05	33.82	yes
mi_rp5_mempct22_prodpct100	231	3.75	77.97	yes
mi_rp5_mempct50_prodpct25	N/A	-0.08	N/A	no
mi_rp5_mempct50_prodpct50	191	2.92	60.77	yes
mi_rp5_mempct50_prodpct75	237	4.87	88.09	yes
mi_rp5_mempct50_prodpct100	263	6.79	103.34	yes
mi_rp5_mempct100_prodpct25	N/A	-0.01	N/A	no
mi_rp5_mempct100_prodpct50	219	5.30	91.02	yes
mi_rp5_mempct100_prodpct75	257	9.41	121.55	yes
mi_rp5_mempct100_prodpct100	277	13.45	152.23	yes
mi_rp10_mempct22_prodpct25	N/A	0.12	N/A	no
mi_rp10_mempct22_prodpct50	176	1.35	28.86	yes
mi_rp10_mempct22_prodpct75	234	2.18	39.15	yes
mi_rp10_mempct22_prodpct100	262	4.06	83.98	yes
mi_rp10_mempct50_prodpct25	N/A	0.17	N/A	no
mi_rp10_mempct50_prodpct50	227	3.69	77.93	yes
mi_rp10_mempct50_prodpct75	263	5.29	92.67	yes
mi_rp10_mempct50_prodpct100	281	7.22	106.69	yes
mi_rp10_mempct100_prodpct25	170	2.77	63.73	yes
mi_rp10_mempct100_prodpct50	246	6.05	96.68	yes
mi_rp10_mempct100_prodpct75	275	9.69	125.46	yes
mi_rp10_mempct100_prodpct100	290	13.78	154.46	yes

* - added value of certification calculated per kg of certified green coffee;
** - relative difference with baseline scenario;
Grey rectangle indicates scenarios with current inclusion to UTZ certification program

Table 10: UTZ certification. Results of cost efficiency analysis

Scenario description	Scenario code	EANB, mil. ugx	BCR	ERR, %	Δ* Household income, %	Sustain-ability
Ongoing program	*rc_mempct22_ prodpct50*	124.31	6.74	229.88	1.99	yes
Ongoing program, Improved inclusion	*rc_mempct50_ prodpct50*	293.56	9.86	293.56	4.57	yes
Ongoing program, Maximum potential	*rc_mempct100_ prodpct100*	955.67	16.82	647.68	14.54	yes
Full self-financing, Current inclusion	*mi_rp5_mempct22_ prodpct50*	-3.36	0.33	-29.31	0.05	no
Full self-financing, Improved inclusion	*mi_rp5_mempct100_ prodpct50*	198.53	7.54	266.6	2.92	yes
Full self-financing, Maximum potential	*mi_rp5_mempct100_ prodpct100*	911.36	16.84	645.68	13.45	yes

* - relative difference with baseline scenario

Figure 1: Model flow chart

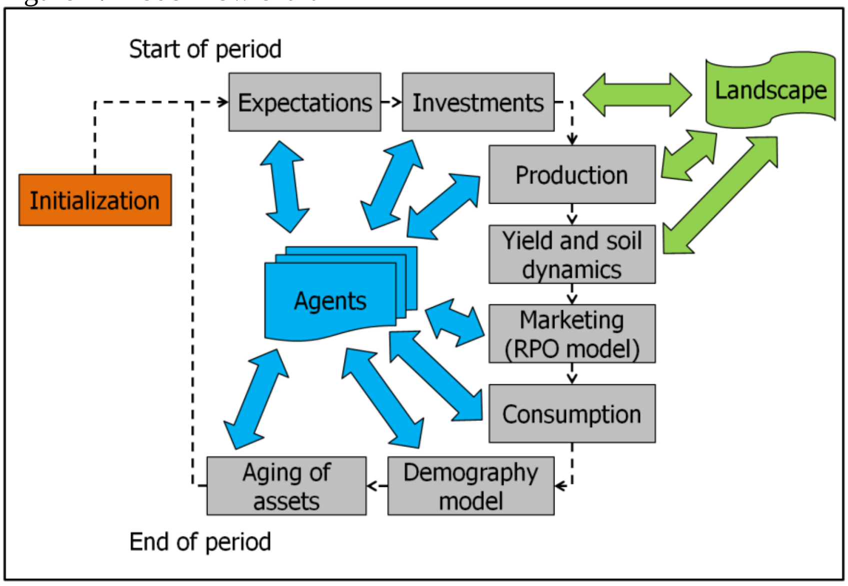


Figure 2: Interaction of household agents and RPO agents

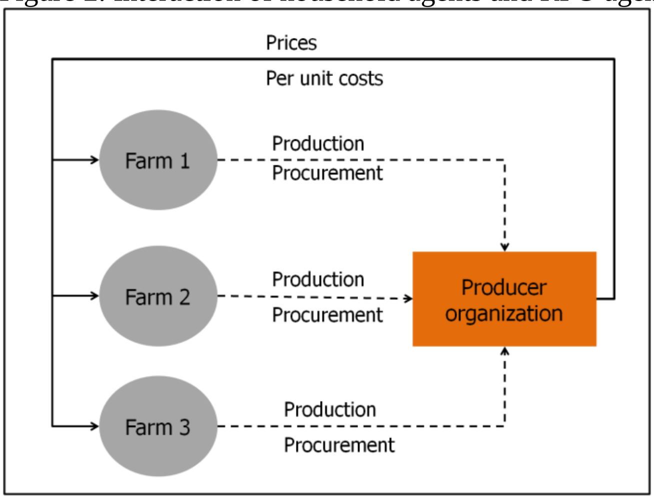
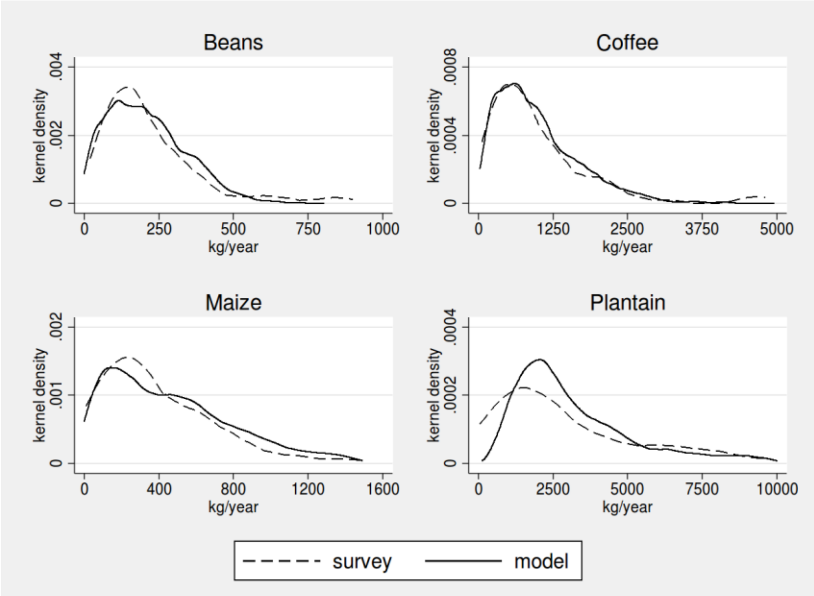
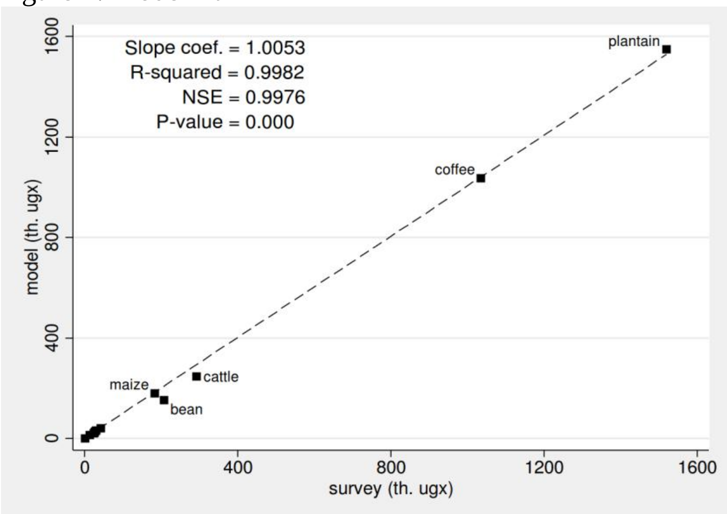


Figure 3: Validation of crop production. Density functions



Production volumes of survey population are estimated from IFPRI (2010)

Figure 4: Model fit



Model results are reported as average over ten test populations

Figure 5: Group certification. RPO agent sales by scenario

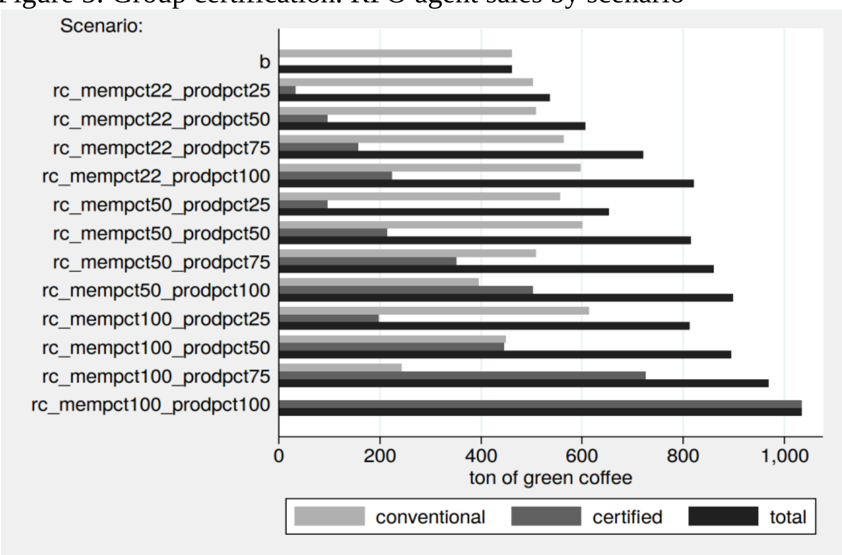


Figure 6: Group certification. Income effect

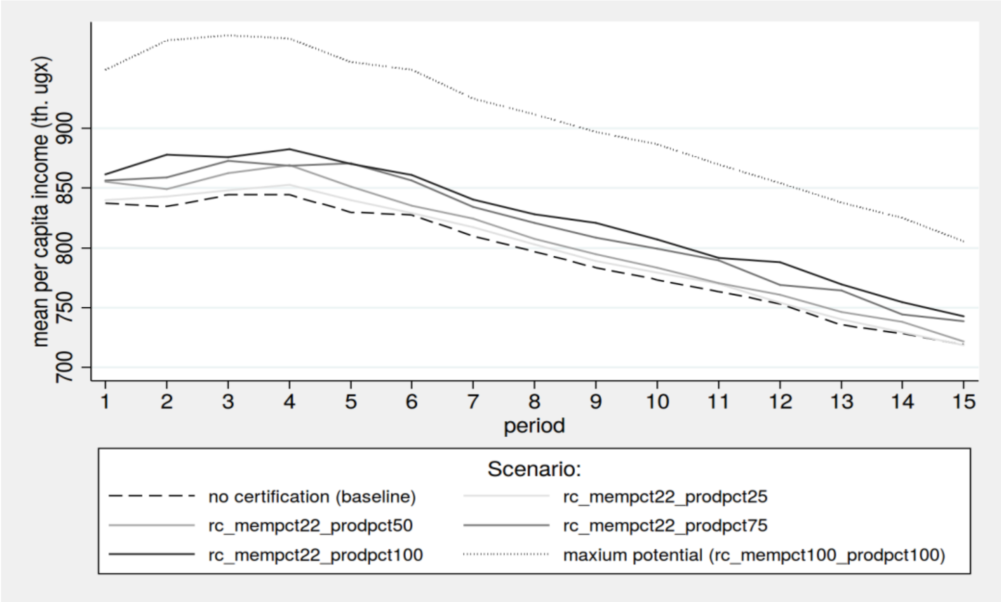
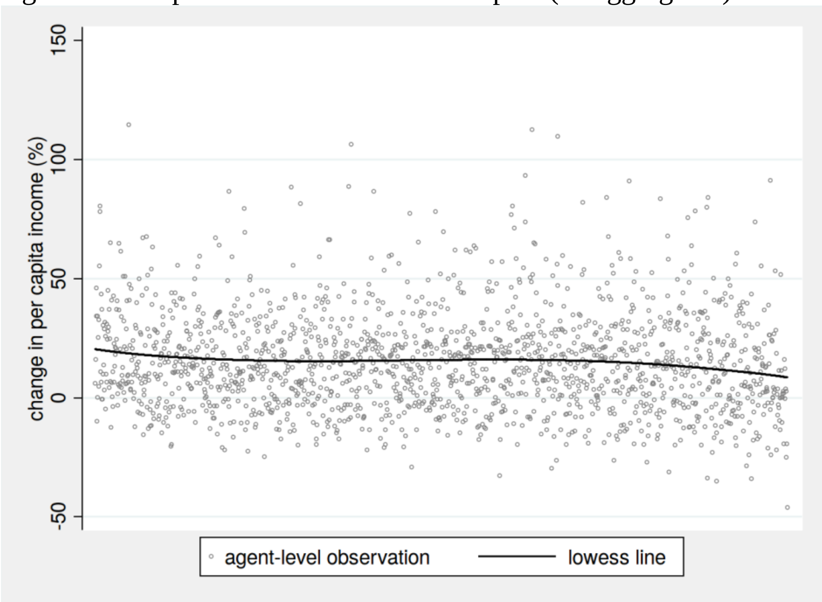


Figure 7: Group certification. Potential impact (disaggregated)



Average result of 15 simulation periods;
Agents are ranked in ascending order according to baseline per capita income