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AN AGENT-BASED NETWORK APPROACH FOR UNDERSTANDING, ANALYZING AND SUPPORTING RURAL PRODUCER ORGANIZATIONS IN AGRICULTURE

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Abstract

Recent empirical findings suggest that empowerment of producer organizations (POs) in agriculture requires an effective targeting and case-specific design of development interventions. By viewing PO as a socio-economic network, we develop an agent-based modeling approach for ex-ante impact assessment of PO support interventions. The paper demonstrates the application of the approach to the example of coffee producers from Uganda and analyzes one of their sub-county level networks more closely. The simulation model is implemented with stakeholder involvement through interactive net-map sessions. The simulation experiments reflect the interventions that are being implemented or considered for implementation by ongoing research of the International Food Policy Research Institute (IFPRI). The predicted effects of interventions are displayed at the levels of the producer organization and individual farming households, emphasizing the importance of careful implementation of future motivation schemes.

Keywords

Producer Organizations, Multi-agent Systems, Socioeconomic Networks, Participatory Approach, Decision Support Systems, Smallholder Farmers, Rural Development

1 Introduction

Smallholder agricultural producers often face market failures and high transaction costs that are associated with dis-economies of scale (POULTON et al., 2010). Low levels of market access and bargaining power, as well as imperfect information prevent many rural producers from benefiting from high agricultural commodity prices (FAFCHAMPS and HILL, 2008). Recent scientific work (KRUIJSSEN et al., 2009, MARKELOVA et al., 2009, SHIFERAW et al., 2008) underlines the potential of rural producer organizations (POs) in overcoming smallholders' obstacles in input procurement and produce marketing. Over the past decade governments and development agencies have put more attention to the empowerment of rural farmers and communities through collective action institutions (WORLD BANK, 2007; IFAD, 2001). However, reality shows that in Sub-Saharan Africa POs have limited success only (BERNARD et al., 2008; GABRE-MADHIN, 2001; AKWABI-AMEYAW, 1997). In order to identify the determinants of PO success and to design adequate measures for effective PO support, empirical assessments of PO performance are required, which are up to now rarely done in case of Sub-Saharan Africa (BERNARD and SPIELMAN, 2009).

This paper presents a novel approach for analyzing and modeling POs as multi-agent networks and demonstrates its application using the example of the organization of coffee farmers in Uganda. In section 2, we define the role of POs in agriculture and discuss the evidence presented in the related literature. Section 3 characterizes POs in Uganda and presents the results of interactive exercises with PO members. The findings from this participatory research help us to create a multi-agent model for one PO and design simulation scenarios, as explained in section 4. Also, in section 4 we analyze the simulated impacts of the development

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assistance to PO. Finally, we present the conclusions from our research on Ugandan POs in section 5.

2 Producer organizations in the context of sustainable development

2.1 Definition of producer organizations

Producer organization in agriculture is an either formal or informal social arrangement with voluntary membership, which pursues the goal of providing economic benefits to its member producers. Agricultural POs can appear in different structural set-ups, such as farmer unions, agricultural cooperatives, village groups, bargaining associations and others, and exist on various levels, from village to international. They can perform an assortment of activities aimed at supporting its members, such as: (i) bulking of produce, marketing and collective sales, (ii) coordination of transport and logistics, (iii) input procurement, (iv) group certification, (v) extension and capacity building, (vi) granting access to financial services and others.

In contrast to other kinds of organizations that are promoted and supported by governments or NGOs, a PO is a business-oriented entity that has to generate additional utility for its members with cost recovery (However, this does not mean that POs cannot receive external grants, subsidies or preferential loans.) In the long-term, POs have to be financially sustainable, like any other kind of business. Contrary to corporations, PO shareholders do not make contributions into share capital in order to make a profit, but to receive certain services and goods. To distinguish POs from private-public partnerships and other externally controlled structures, it is important to note that producers are the main shareholders of POs.

2.2 Relevance for the development agenda

Improvement of livelihoods of smallholder farmers by enhancing their profitability and sustainability is the primary pathway to poverty reduction, stronger adaptive capacity and minimal vulnerability to global change processes. WORLD BANK (2007) emphasizes the vital role of the smallholder farm sector as "one of the cornerstones of an agriculture-for-development strategy", and estimates 1.5 billion people in the world to be involved in smallholder agriculture (i.e. farm households with 2 hectare or less). In developing countries smallholder agriculture is often subject to inefficient allocation of goods and services and other forms of market failures. Responding to the market and government failures is a driving force for PO formation and development in developing countries.

Smallholder farmers all over the world are facing two challenges related to the size of their enterprise. It is their inability to reach benefits of external economies of scale when acting independently on the market and their low bargaining power compared to upstream and downstream industries (VALENTINOV, 2007). Uniting together small and medium farmers under the umbrellas of POs can potentially help them to overcome these two problems, by providing links between producers and consumers, building missing capacities and bridging existing knowledge and technology gaps between them and today's leading producers (SHIFERAW et al., 2008; BACON, 2005). In terms of rural development that means:

- Improvement of rural livelihoods
- Linking small producers to national economies
- Improvement of competition in rural areas by provision of alternative sales channels
- Vulnerability reduction through organization of community-based institutions and self-help groups

A review of scientific literature found empirical evidence of POs` contributions to farmers' welfare improvement. Studies reveal that participation in the cooperatives leads to an increase of selling prices and thus household incomes of member producers (e.g. SHIFERAW et al.,

2008, WOLLNI and ZELLER, 2007). A few studies outline the positive impact of POs on the provision of market linkages to rural farmers and effective transmission of information (WOLLNI et al., 2010; ULIWA and FISCHER, 2004).

Creation of employment opportunities in rural areas is another important effect of the PO presence (SCHWETTMANN, 1997). According to DEVELTERE and POLLET (2008), these effects can be (i) direct (staff of POs and related institutions), (ii) indirect (support of members' self employment), (iii) spillover (non-members, whose employment is dependent on existence of cooperatives).

Also, a number of cases (WOLLNI et al., 2010; DEVAUX et al., 2009; KRUIJSSEN et al., 2009) highlight contributions of POs towards the sustainable management of natural resources and the adoption of good production practices.

2.3 Supporting producer organizations

In the past, the niche for POs was often defined as mediators for social support for disadvantaged groups of population, as DEVELTERE and POLLET (2008) conclude from their analysis. The authors, however, admit that the situation has changed. Now, POs are mostly considered as profit-generating private entities. Such current business-oriented approach puts more emphasis on issues like financial viability and independence, solvency, profitability, sustainability and investment returns. Therefore, the development of strategic business capacities such as planning and analytical skills of PO leaders as well as support for managerial decisions is important for successful performance of POs.

External support to POs shows not only successful but also disappointing examples as supporting activities may stimulate opportunistic and rent-seeking behavior. Many researchers point out that effective targeting and case-specific designs of supportive mechanisms are the keys for facilitating formation of POs, empowering them and guiding their transition to economic independence and sustainability (MARKELOVA and MWANGI, 2010; BERNARD and SPIELMAN, 2009; BERNARD et al., 2008; LYON, 2003). This, in turn, requires a deeper understanding of functioning of POs and their farmer members and a proper ex-ante assessment of impacts of proposed development interventions.

3 Networks of producer organizations: A case of Ugandan coffee farmers

The work presented in this paper is part of the research project "Working together for market access: strengthening rural producer organizations in Sub-Saharan Africa", funded by the German Ministry of Cooperation (BMZ) and led by the International Food Policy Research Institute (IFPRI). Project activities took place in 2009-2012 in Senegal and Uganda and concentrated on the marketing potential of local POs. This project is part of a larger IFPRI research program "Institutions and Infrastructure for Market Development", which explores various policy and development topics related to the role of rural infrastructure and institutions in improving the market access of smallholder farmers.

3.1 Producer organizations in Uganda

As was assessed during our field work in Uganda, agricultural POs in Uganda are mainly engaged in marketing of produce and generation of additional value by means of product transformation, grading and/or packaging. Commonly, they are formed according to one or several agricultural commodities they market (coffee, maize, sunflower etc). In most cases producers are organized at two levels:

1. Primary farmer organizations (POs) unifying farmers from the same village or parish.
2. Sub-county level associations, usually called depot committees (DC) or area cooperative enterprises (ACE).

Typically, POs are responsible for bulking the produce of individual farmers and coordination of transport for delivering produce to DC/ACE. Collection of PO-gathered quantities, product transformation, value addition, coordination of market sales and input procurement is organized at the DC/ACE level. Farmers may deliver the produce to the DC/ACE individually bypassing the first level organization. DC/ACE is a small-scale producer union consisting of several POs from the same sub-county. According to IFPRI (2010a), most DC/ACEs in Uganda are involved in agricultural extension (95.2% of DC/ACEs), marketing (90.5%) and provision of market information (81%). The DC/ACE is usually not bounded to a certain buyer and is able to bargain for better deals. Further, the DC/ACE may be a member of a country or region-wide union or federation, like the National Union of Coffee Agribusinesses and Farm Enterprises (NUCAFE), Uganda National Farmers Federation (UNFFE) and others. These umbrella unions have advocacy and representative functions, serve for lobbying interests of agricultural producers, and facilitate access to buyers, financial services and certification schemes. There are several constraints that are hindering the development of the DC/ACE-based system of cooperative marketing. During the IFPRI (2010) survey, managers of DC/ACE were asked to list the three most important constraints that the DC/ACE is facing. The most frequently mentioned constraint was liquidity (reported by 57.1% of DC/ACEs) and transportation (52.4 %). Low liquidity forces DC/ACEs to delay payments to farmers for the delivered quantities; such delays may discourage farmers from selling their produce through the PO-channel. Low transportation capacities lead to additional transaction costs, which are associated with vehicle hire. There are also other issues that, despite being rarely mentioned, received highest importance rank such as mistrust among members, poor management skills and low access to market information. Their occurrence might lead to a notable decrease in market efficiency of the DC/ACE.

3.2 Participatory assessment of a socio-economic network

POs are complex socio-economic systems that consist of multiple elements, processes, stakeholders and relationships. In order to understand those, we applied Net-Map, a visualized participatory method of systems and networks mapping (for a detailed explanation of the methodology, see RAABE 2011). The application of the tool has several benefits in comparison with the possible alternative use of "classical" focus group discussions:

- Provision of systems view and process-understanding
- Visualization of the differences between groups
- Identification of process leaks, weak linkages, overlaps in responsibilities and potentials for improvement
- Facilitation of the follow-up discussion that reveal more insights on farmers behavior and decision-making
- Assessment of production and marketing network in an agent-based way consistent with a chosen approach of simulation modeling (see section 4).

This participatory approach was applied in the "Kibinge coffee farmers association" (Kibinge DC) - a sub-county level farmer-owned organization that specializes on processing and marketing of *Robusta* coffee. The DC and its members are situated in the Central region of Uganda, Masaka district, Bukomansibi county, Kibinge sub-county, a traditional coffee-growing area. The DC was founded in 1995 and registered as a cooperative in 2008. It offers a wide range of services, such as training on agricultural practices, provision of planting material and transport management. The Net-Map exercise was conducted in groups of five respondents, once with the administration of the studied DC and ten times in different POs of the DC (55 respondents in total). The output of the Net-Map exercise is the map of socio-economic network where actors, their links and roles are reflected. Along with the Net-Map

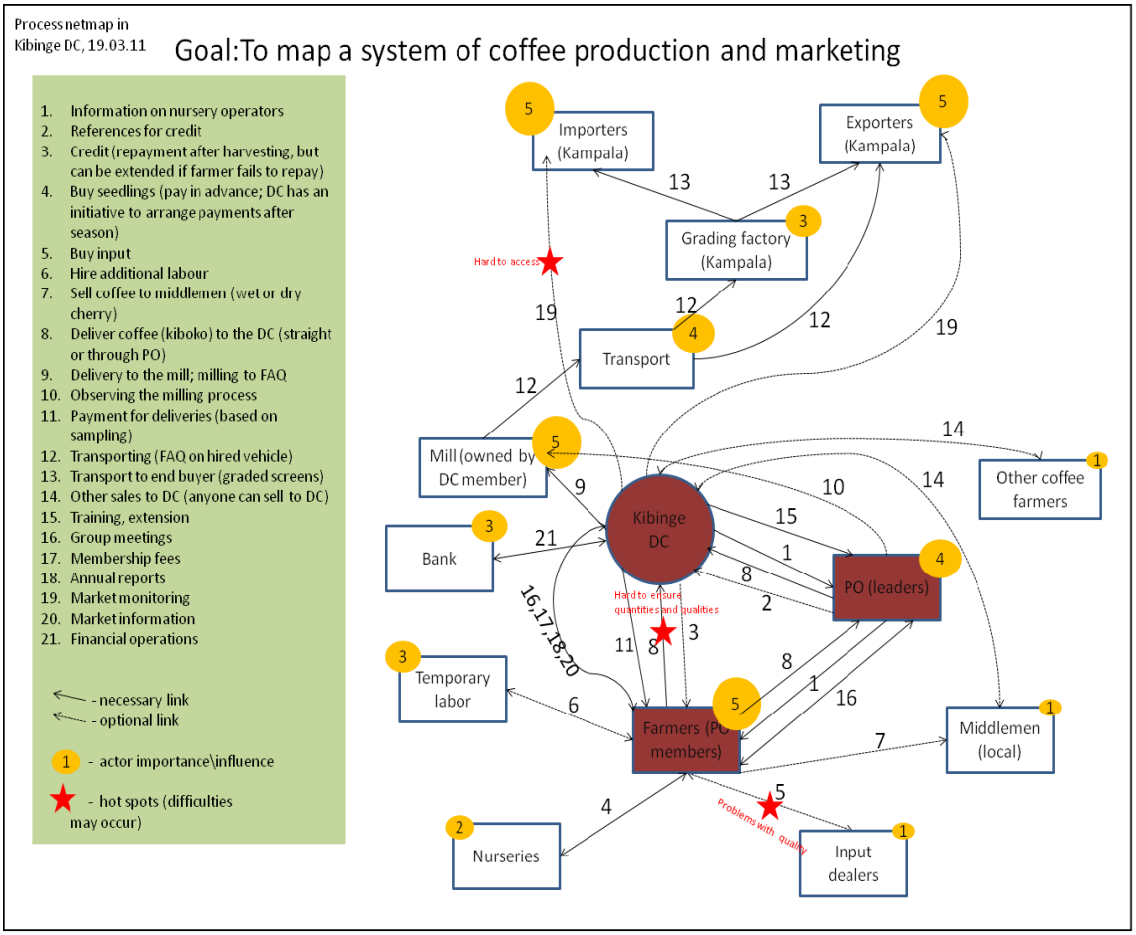
exercise we conducted public goods games in the same ten PO respondent groups. Participants received some cash at the beginning of the session and could discreetly decide on how much of these funds they wanted to contribute to a common pool. The total amount of individual contributions would then be multiplied by 1.5 and split among all participants at the end of the session. Game results from these experiments were later compared with the statistics on coffee sales of the respective POs.

Figure 1 contains the output map of the Net-Map session with the DC administration. The figure displays the process of coffee production and marketing in Kibinge sub-county and characterizes the involvement of the DC. During the mapping sessions in Uganda, we also applied other participatory methods (along with Net-Map) to study the socio-economic network of the PO: (i) group discussions with farmers (as a follow-up) and (ii) public goods games. In general, the application of participatory techniques provided a lot of useful insight, explanation and reasoning that improved the researcher's understanding of POs, and allowed an understanding of the challenges in the study area. The results of the participatory sessions informed the choice of modeling concepts, decision-making mechanisms and assumptions for the simulation model.

The main findings of the participatory research of the coffee producers' network are as follows:

- POs are facing a strong competition for member produce from of local middlemen traders. Although POs are able to offer better selling prices, often farmers choose not to sell their produce through it. The main reasons for taking such a decision are: (i) payment delays that occur when selling through the PO-channel and (ii) informal future contracts that farmers make with middlemen in order to obtain cash before the harvesting season. In addition, (iii) the share of coffee produce that a PO-member decides to sell through the organization could be explained by his behavior in a public goods game. Therefore, it is positively related to the individual's trust to other PO-members and his cooperativeness, which is approximated by his public goods game contribution.
- There is a general lack of understanding of the other PO services (credit and input provision) from the member side. Rules for obtainment of services appear to be unclear and non-transparent, which creates negative farmer attitudes in some cases.
- Farmers due to their remoteness, have low access to mineral fertilizers, pesticides and quality planting material for their coffee and in some cases to seasonal labor. This negatively affects productivity of coffee plantations.
- There are general problems with credit access, as loans from POs are relatively small and unreliable. Only few POs (4 out of 10) have links to formal financial institutions.

Figure 1: Network of a producer organization



Source: Authors

4 Using a multi-agent model as a tool for analysis and support of producer organizations and their members

Development studies require deeper understanding of household-level heterogeneity. It is typical to observe large variations in yields, input application intensity, crop mixes, crop management practices etc. between farming households in developing countries (RUBEN and PENDER, 2004; SCHREINEMACHERS and BERGER, 2006).

For example, the IFPRI (2010a) survey reveals that in Uganda rural household can produce and sell up to nine different crops and five livestock products in one agricultural season. There are a lot of constraining factors that are causing such diversity: limited resource endowments, poor rural infrastructure, climatic uncertainty, soil degradation, imperfect markets, etc. Capturing the discussed variations with aggregate modeling approaches is infeasible, since it would require a large number of control variables. In this respect, multi-agent systems (MAS) are a promising alternative (BERGER et al., 2006).

Also, there are certain advantages of using MAS for modeling POs. POs are complex systems integrated to socioeconomic networks, as it can be seen from figure 1. Interactions between PO members, the PO itself and the environment are important factors to consider and model. Also, a much broader set of development interventions can be assessed with MAS in comparison to experimental approaches and it does not involve a risk of causing negative effects on subjects of intervention. Moreover, modeling often has higher time and cost efficiency. Moreover, once created a model concept and implemented in a source code, upscaling of model results can be done with minor additional contributions.

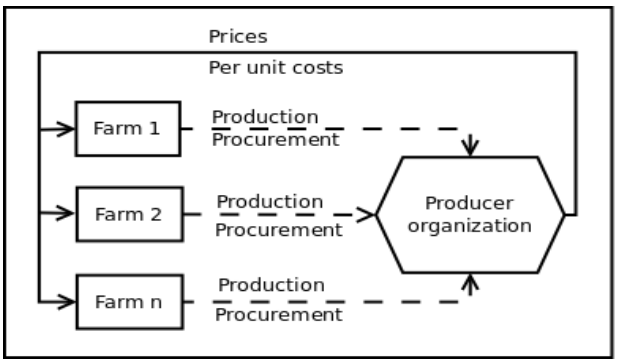
4.1 MP-MAS modeling framework

To model a PO, we used the MP-MAS software, which is a multi-agent software package of household-based economic decision-making (for software description, see SCHREINEMACHERS and BERGER, 2011). Its country application for Uganda is coupled with a biophysical model of crop growth and soil dynamics as well as with livestock and demographic models building on the study of SCHREINEMACHERS et al. (2007). MP-MAS applications belong to the family of models called "multi-agent systems applied to land use/cover change") (see PARKER et al., 2003). The MAS of this type combine (i) a landscape model represented by cellular automata and (ii) a model replicating decision-making of land users represented in an agent-based way. Integration of the two parts is implemented through the determination of interactions and interdependencies between agents and the landscape. Figure 3 displays the flow chart of the MP-MAS Uganda model. After the MAS is initialized, simulation steps address a pool of variables (such as soil properties, household characteristics, market prices, etc.). Respective calculations supply information for the next steps and redefine variables, thus providing interactions between various components of MAS.

POs are introduced to the modeling framework as a specific agent type, in addition and different from farm household agents as in the original version of BERGER (2001). Since POs work with farm households in many ways, the PO agent also interacts with farm household agents. Farm agents "send" to POs their production, membership fees and inquiries for inputs, which serve as exogenous variables for the decision-making module of the PO agent. The PO agent in turn "feeds" back to farm agents the sales prices and per unit costs, which influence their decision-making. Figure 2 schematically displays the interaction process between the two agent types. In this way, PO and household agents influence each other's behavior.

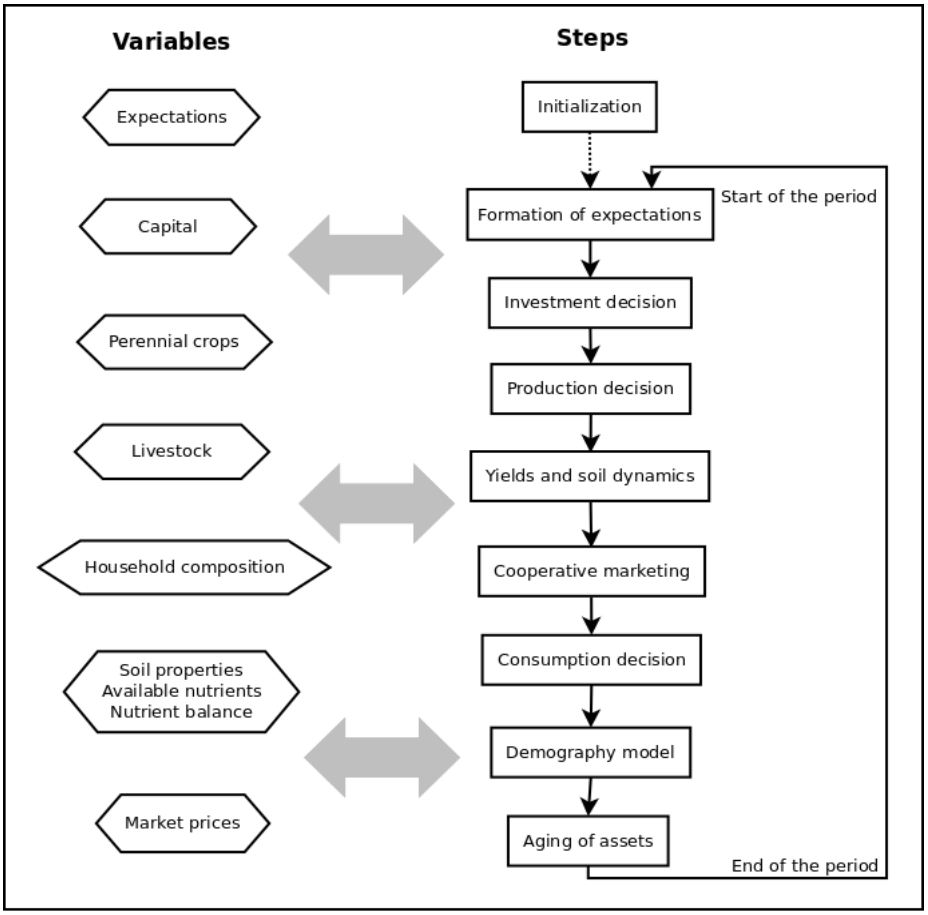
The MP-MAS Uganda application models the Kibinge DC itself, all related POs, member farming households (n=1716) and their household members (n=11911), which translates into 1716 farm agents (one-to-one correspondence with real-world households) consisting of 11911 household members. The DC is represented by an additional agent of a PO-type. The parameterization of model agents was derived from the data of IFPRI (2010) project survey and findings from our field work in Uganda (LATYNSKIY and BERGER, 2011). The applied modeling methodology is fully described in LATYNSKIY and BERGER (2011) and LATYNSKIY and BERGER (2012).

Figure 2: Interaction of farm and PO agents in MP-MAS



Source: Authors

Figure 3: Simulation cycle of MP-MAS Uganda



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4.2 Assessing the impacts of developing interventions: Shortening payment delays

Focus group visits of the IFPRI project (DEJENE-AREDO et al., 2009) and our own interviews with key informants (LATYNSKIY and BERGER, 2011) indicated the importance of timely payments for production of farmers. Selling through the PO implies a certain delay in payment (due to coordination of the collection of individual produce, product transformation and banking operations), while when selling to a trader coffee growers are paid on the spot. Given the high rates of time preference of farmers in the study (table A1), shortening the time that farmers have to wait in order to receive their payments from POs, may increase their willingness to market their produce through POs, increase the PO turnover and, therefore, make the PO benefit of fixed-cost degression. Hence, MP-MAS Uganda is used to test the sensitivity of coffee sales volumes and possible delays associated with selling through the PO-channel. With our simulation experiments, we test the hypothesis that shortening payment delays would have a positive impact on sales volumes of Kibinge DC and assess the impacts of this intervention on the household level.

Model output (figures A1-A3) suggests that the quantities of coffee sold through the PO-channel vary significantly depending on the length of payment delay (see figure A1). According to the IFPRI (2010a) survey, Kibinge DC usually pays to members seven days after they delivered their produce to the DC. Simulation results suggest that by paying on the spot, DC may increase its turnover about two times, when compared to the situation of weekly delay. This would translate into a better selling price for the PO members, which in turn would increase farmers' revenue from coffee sales and improve their incomes (see LATYNSKIY and BERGER, 2012). As can also be seen in figure A1, payment delays of two month and more dis-

courage all PO member agents from selling through the organization and therefore make the PO unable to cover its fixed costs (staff wages, electricity bills, etc).

The high sensitivity to payment delays is caused, on the one hand, by the high time preferences of farm agents (table A1) and, on the other hand, by small margins of local traders (DEJENE-AREDO et al., 2009; IFPRI 2010a) (the prices they offer are competitive).

Figure A2 shows the simulation results for the development of household cash earnings under situations (i) with current payment delay, (ii) no payment delay and (iii) absence of the PO selling channel. From this figure it can be seen, that PO-marketing has a positive impact on cash earnings of member agents. However, significantly higher impacts could be achieved, if member agents were paid on the spot.

4.3 Assessing the impacts of developing interventions: Producer motivation schemes

In order to encourage farmers to sell more output through the PO-channel, Kibinge DC is considering to experiment with various monetary motivation schemes for its members (LATYNSKIY and BERGER, 2011). The MP-MAS Uganda model could be used as a tool for analysis of their effects, especially in how far they might encourage farmer to increase his production and delivery to the PO. Therefore, monetary motivation alternatives considered for implementation in the Kibinge DC are currently being introduced in MP-MAS. By iterative MP-MAS simulations one could make the optimal choice of set up of the motivation schemes. MP-MAS results may support this decision from different perspectives: PO turnover, budgeting, household sales revenue and household income.

The particular strength of MP-MAS is that it is capable to disentangle the effects of interventions on the level of individual households. As a short example, figure A3 demonstrates the impact of one of the tested motivation options (provision of proportional premium for high volume sellers) on farm revenue from coffee sales. From this figure it can be seen that the tested intervention is expected to have diverse effects on household revenue. It would not be possible to capture this type of effects with aggregate simulation models.

The simulation results, which are fully reported in LATYNSKIY and BERGER (2012), indicate that the various schemes considered for producer motivation may have contrasting effects. Some options of implementation stimulate an increase of the DC turnover which, in turn, increases the profit margin of the DC and, therefore, improves its sustainability. On the other hand, some options of implementation may have a discouraging effect on producers as a whole that results in the reduction of DC sales volumes. Our simulation results so far suggest that the provision of monetary schemes for producer motivation is not a straight-forward decision. The improper design of such schemes could result in discouragement of producers, which in the worst case may lead to PO break-down. With the ongoing MP-MAS Uganda research, we hope to be able to support the design of future motivation schemes.

5 Conclusions

The evidence from developing countries underlines the potential that POs possess for improvement of rural livelihoods and, therefore, farmer's adaptive capacity in the context global change. However, adequate assessment tools are needed for support of PO decision-making, ensuring its sustainability and effective organization of development assistance. MAS models that simulate the socioeconomic and biophysical processes and interactions of farmers and their producer organizations represent a promising tools in this context.

In our case study in Uganda we made the following experience:
Considering POs as networks, rather than indivisible objects, and applying related research methods, such as Netmap and MAS, together with the inclusion of stakeholders in the research provides deeper insights on PO functionality, problems and improvement potentials.

Aggregate macro-level models may appear too rigid for the analysis of development interventions, since, due to a high heterogeneity of farm households in developing countries, they are likely to overlook the micro-level effects. Therefore, "bottom-up" agent-based approaches should be considered for implementation by development economists.

Simulation results obtained so far suggest that shortening the delays of farmer payments is beneficial for the PO as a whole and its members. Therefore, a provision of liquid means to POs for organization of payments on the spot should be considered for implementation in practice.

The organization of monetary motivation schemes for PO member producers requires solid ex-ante analysis, since our simulation experiments indicate the sensitivity of motivation impacts with respect to the set-up of such schemes.

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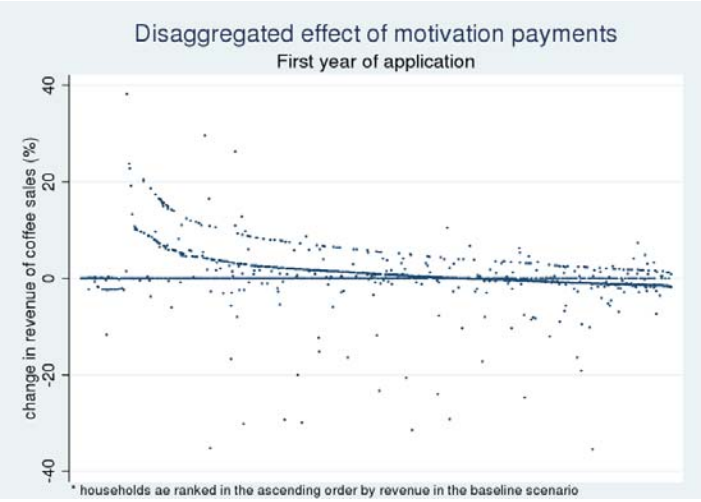
Appendix

Table A1: Time preferences of Kibinge coffee producers

Monthly rate of time preference	Frequency	Percent
0-5%	15	21.4
5-10%	7	10.0
10-20%	11	15.7
20-50%	5	7.1
50-100%	17	24.3
>100%	15	21.4

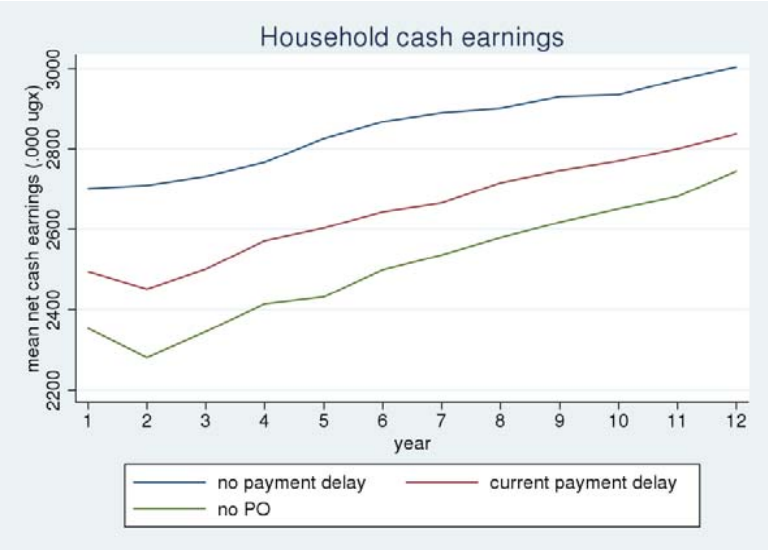
Source: own estimations from IFPRI (2010a)

Figure A1: Sales of Kibinge DC



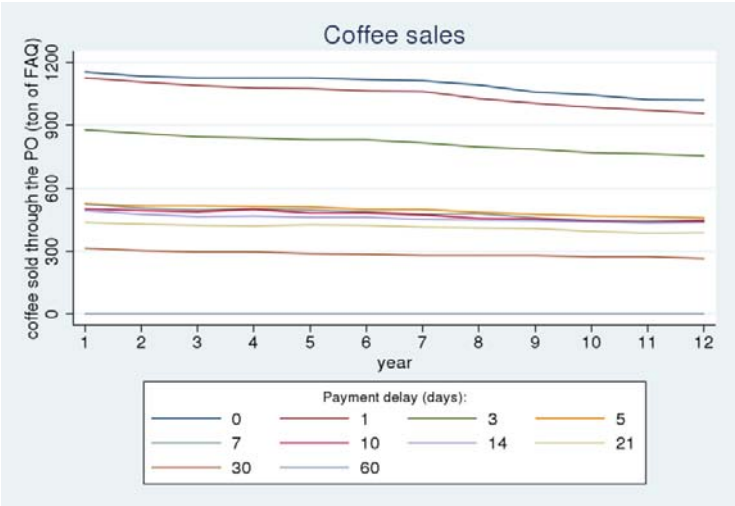
Source: Authors based on MP-MAS simulation results

Figure A2: Household cash earnings



Source: Authors based on MP-MAS simulation results

Figure A3: Disaggregated effect of motivation payments



Source: Authors based on MP-MAS simulation results