Simulating the role of trust in supply development

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Abstract. Fostering of inclusive business aiming to involve low-income communities in value chains is a recent approach to alleviate poverty in developing countries. The approach requires new impact assessment tools to measure changes in farm income and transaction cost, and behavioural change in value chain relationships. An agent-based simulation combined with games is proposed for the assessment of a project developing sorghum production and marketing in Meru County, Kenya. Contracts between a local sorghum processor and smallholders have a central role. Trust between farmers and the processor and mutual trust in farmer groups are key success factors. The simulations indicate that the approach can lead to increased farm incomes. Continuity of the contract system depends on the extent to which contracted farmers can be trusted not to side-sell when market prices are high. However, the simulated production remains at an increased level even if the contract system breaks down.

Keywords: agriculture, value chain, trust, risk aversion, Kenya

1 Introduction

In current development policy, fostering of inclusive business is considered a promising approach to alleviate poverty. Inclusive business is to be understood as sustainable and commercially viable business that involves low-income communities in value chains, in a way that is benefitting them [1]. NGOs develop inclusive business in partnerships with firms that have interests in reliable local supply. In such partnerships, issues are to be solved like high transaction cost for firms sourcing from large numbers of poor suppliers, cost of logistics, firms' trust in the suppliers' capacities and commitment to the relationship, suppliers' trust in firms to accept their produce and pay as promised, and availability of knowledge, capital, and inputs to the suppliers [2]. NGOs and firms are assumed to have complementary capacities and resources to solve these issues [2].

New impact assessment approaches are required to evaluate public-private partnerships aiming at supply development. Topics to be measured include changes in farm income and transaction cost, and behavioural change in value chain relationships. The research reported in the present paper focusses on an agent-based simulation, as part of a project developing a value chain laboratory for impact assessment of supply development programmes. In the concept of the value chain laboratory, agent-based simulations mirror simulation games with actual value chain participants, following the symbiotic gaming and agent-based simulation approach as proposed by Tykhonov et al. [3]. Thus, an environment is offered where data can be gathered, hypotheses about the processes can be tested, and alternative regimes can be experimented with.

The context of this research is the 2SCALE programme [1]. 2SCALE aims to improve rural livelihoods and food and nutrition security in 9 African countries. 2SCALE forges public-private partnerships, with private partners varying from local producer organisations and SMEs to large-scale companies such as seed companies, processors, and trading companies. The approach is based on (1) formation of agribusiness clusters (local networks between the producers themselves and with service providers) to improve competitive intelligence and bargaining power, (2) integrating the agribusiness clusters in value chains, with backward linkages to input supply chains and forward linkages to food supply chains, and (3) enabling fair business environments with better access to information and finance, in particular for the weaker actors [1].

The following sections describe the agent-based simulation of the 2SCALE initiative in Meru County, Kenya. This initiative aims to increase the production of sorghum and to develop stable and sustainable relationships of farmers with a local sorghum processor that delivers to the beer industry. A value chain analysis was conducted to gather data about sorghum production and marketing in Meru County. Desk research was combined with a mission to Kenya for a detailed value chain mapping exercise. During this mission, semi-structured interviews were held with 1 sorghum processor, 2 farm input suppliers, 2 financial service providers, 5 farmer groups (in total 97 farmers), and the Ministry of Agriculture (MoA). Key topics for the interviews were marketing channels, trust, contracts, group dynamics, and transaction cost related to marketing of the sorghum. Section 2 describes the sorghum value chain in Meru County, based on the report of the value chain mapping and the report of the baseline survey for the quantitative evaluation of 2SCALE, which were both performed by partners in the 2SCALE evaluation. The central issues trust, honesty, and risk attitude were measured using trust and risk preference games. Section 3 describes the games played in Meru County, Kenia to gather data on these topics. Section 4 proposes the agent-based simulation informed by the collected data. Section 5 presents observable emergent properties (such as harvest, contracts, compliance, farmers' incomes, transaction cost) and results of a sensitivity analysis. The paper is concluded by a discussion in Section 6.

2 The sorghum initiative in Meru County

The value chain analysis resulted in the value chain map as depicted in Fig. 1. In Meru County, approximately 10,000 smallholders produce sorghum, among other crops. Typically, they grow sorghum on 0.1 to 10 acres (average 1.6 acres), in two seasons per year, with harvests in March and September. Productivity, as stated by farmers participating in the supply chain games, varied widely between farmers, ranging from less than 50 kg to over 2000 kg per acre (average 880 kg). The low productivity is also due to lack of income to purchase inputs, such as high-quality seed, fertilizers, pesticides, packaging materials, and threshing services [4]. The processor organizes collective purchasing of such inputs and provides training and advice to the farmers. Financial services are available to provide loans for input and other services to contracted farmer groups, but loans are not mandatory for a contract to deliver to the processor. To receive a loan, a farmer group must stand surety for its members. So, if an individual farmer fails to pay back the loan, his/her debt must be paid back by the other group members.

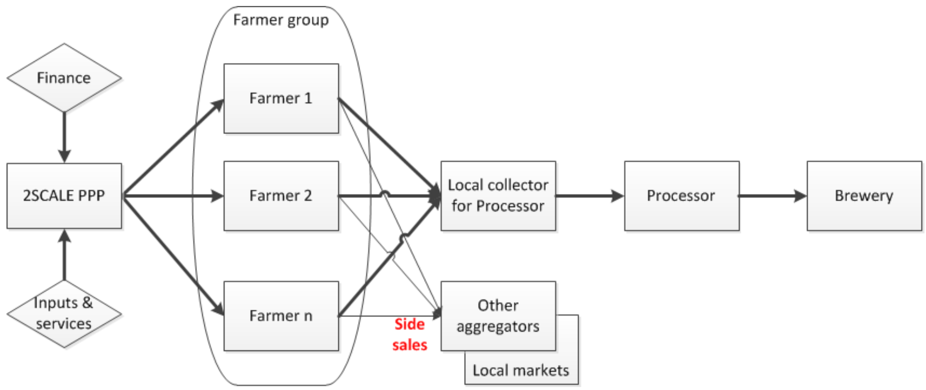

Fig. 1. The sorghum value chain in Meru County, Kenya

A local sorghum processor is the private partner in the initiative. This processor collects sorghum to be used as a raw material for beer production. The processor has a contract with the brewery stating the volume and minimal quality to be delivered. The processor associated with 2SCALE contracts farmer groups to produce this volume of sorghum of sufficient quality. A fixed contract price is offered prior to seeding to each farmer with a relatively attractive price compared to average prices on other markets. In 2015, this price was 25 KES per kg. This lifts the risk of price fluctuations off the farmers. Groups can receive a price premium if they collectively deliver more than what can minimally be expected given the natural conditions and the amount of inputs applied (up to 2 KES per kg in 2015).

Farmers can have several reasons not to deliver (part of) their harvest according to contract. Need for cash may urge them to side-sell part of their harvest and side-selling may occur if buyers passing by offer good prices to be immediately paid in cash. Offered prices range from 20 KES to 27 KES per kg. By contracting farmer groups, the processor aims to hedge the risk of individual farmers side-selling to other aggregators. To control transaction costs the processor has implemented a network of collection points with adequate storage facilities in the farmers villages, where contracted farmers can deliver their produce. These collection points collect solely for the processor. The processor collects the sorghum from these local collection points, and transfers it to the beer brewery.

Trust, honesty, and risk attitude are assumed central issues in this value chain. The processor must trust the farmers to deliver a sufficient volume to fulfil its contractual obligations to the brewery. Side-selling may occur for two reasons: (1) farmers' urgent need for cash and (2), if market price is high, opportunistic behaviour depending on the farmer's honesty. In case of large-scale side-selling, the processor must buy sorghum form other sources. On the other hand, contracts may hedge the farmers' market price risk, but farmers must trust the processor to pay promptly after delivery and to pay the agreed price. Farmers must also trust their fellow group members to deliver their full harvest in order to cash the volume premium and to redeem their loans. Games were used to gather data on these issues.

3 Description of the games

Data was gathered in games from 20 June till 2 July 2016. Two Dutch researchers gathered the data, each aided by a local research assistant, who also was acted as translator. All were extensively trained on objectives, processes, and procedures of the games. Prior to the games with farmers, trial games with local program partners were conducted. Games were played with 15 farmer groups, each consisting of 16 farmers. Of these, 10 were treatment groups targeted by the intervention, and 5 control groups. Groups were located within a 2 hour car drive from Meru town. Groups were selected by the research team, in collaboration with the sorghum processor participating in the intervention. Treatment groups consisted of the group leader and 15 farmers randomly selected by the research team from the group member list provided by the processor. Control groups consisted of a group leader and 15 farmers selected by the group leader, because the research team did not know the group members.

To estimate parameters on trust, trust update, risk, and honesty, three types of behavioural economic games were conducted: trust games [5], Voluntary Contribution Mechanism (VCM) public goods games [6], and risk preference games using paired lottery [7]. In the trust games, farmers were divided in two groups. Each farmer in group A received an initial amount of 10 coins. (S)He sent a fraction of these to a farmer in group B, but the farmer in group A did not know who. This amount was recorded and tripled by the game leaders, before it reached the farmer in group B. The farmer in group B decided how much of this amount to send back to the farmer in group A. This amount was recorded and forwarded to the farmer in group A. Trust is computed as the fraction of the coins the farmer in group A sent to the farmer in group B. Two trust games were played between farmers (1 from group A to B, and 1 vice versa), 1 trust game between farmers and the processor participating in the intervention (treatment groups) or their usual sorghum buyer (control groups) and a new sotghum buyer, and 3 consecutive trust games between the farmers and a new sorghum buyer. In the VCM games, all farmers contributed a fraction of their initial amount of 10 coins to a public account, and stocked the rest in a private account. The amount in the public account was doubled and then equally shared among all participants. Group trust is the fraction of the coins a farmer contributes to the public account. Three consecutive VCM games were played. Playing consecutive trust games allowed for measuring trust update parameters, i.e. of the development of trust after a positive or negative experience. To ensure real behaviour as much as possible, each coin in the trust and VCM games represented 1 Kenyan shilling. In the risk preference game, a multiple price list was used with six choices between option A, ”win a certain amount of money” (10, 20, 30, 40, 50, or 60 KES), or option B: ”flip a coin” (head 60 KES, tail 0 KES). The amount at which a farmer decides to switch from option B to option A is a measure for risk attitude.

The games, introduction, and payment lasted 5 to 6 hours. At the end of the day, all farmers were paid the amount they had won in the games (average 145 KES; st.dev. 24 KES). In addition, they received a fixed amount of 200 KES for transportation. Prior to payment, farmers filled in a questionnaire with questions on personal characteristics (age, gender), production (land area with sorghum, yield of most recent harvest), marketing (buyer, period of relationship with buyer) and trust (in group members, in sorghum buyer). Summaries of the game results are included in the next section.

4 Description of the agent-based simulation

A simulation of the sorghum value chain has been implemented in NetLogo [8]. The present section describes the simulation following the updated ODD protocol [9].

Purpose. The purpose of the simulation is to evaluate value chain development projects with respect to the role of trust and opportunities to hedge risk and reduce transaction cost. The application domain is a sorghum supply chain in Kenya where a processor aims to contract smallholders to deliver their produce for beer brewery.

Entities, state variables, and scales. Active entities in the simulation represent plots of land, farmers who cultivate the land, and processors who contract farmers to deliver their produce. The present simulation sets up a single processor. Input suppliers and the brewery are not represented as agents. The farmers are organized in fixed groups, headed by one of the members. The groups are not represented as entities; all farmers have a state variable pointing to their group head and a state variable comprising the set of group members. Farmers maintain a list of processors they know and maintain an associated list of trust they have in the processors. In addition to their trust in the processor, farmers maintain trust in their group and have a risk attitude and an honesty parameter as personal properties that affect their decisions. Processors maintain a list of the farmers and associated lists of trust, contracts, and deliveries with each of these farmers. The agents operate in an environment where natural conditions and market prices are for each growing season randomly drawn from user-specified intervals. A simulation run typically includes approximately 10,000 farmers (in groups of 16) and a single processor, and typically spans a period of ten years, with a time step of half a year (one sorghum cropping season). For further details, see the simulation program[1].

Process overview and scheduling. Fig. 2 represents a time step in the simulation cycle. The processor sets the contract conditions; then the farmers decide whether to apply for a contract, based on their risk attitude and trust in the processor, and may apply for for a goup loan based on the trust in their goup members. Depending on their cash balance or the availability of a loan, the farmers can invest in inputs, sevices and skills, which determine - together with random natural conditions - the yield. Market price and natural conditions are in each time step randomly generated on intervals which can be set in the user interface. Then, if they have a contract, farmers decide whether to comply or sell to side markets. Reasons to side-sell are urgent financial need and opportunism. The probability of opportunistic side-selling depends on a farmer's honesty parameter and the current market price. Side-selling negatively affects the processor's trust in the farmer. In addition, it negatively affects group trust among the farmers, because of lower group delivery bonus and mutual responsibilty for group loans. Thus, compliance and defection by the farmers are simulated based on personal characteristics set in the user interface, cash balance resulting from previous growing seasons, and market prices. The processor will always comply, unless the user presses the DEFECT button during the simulation to study the effects on the system of such behaviour. The DEFECT button makes the processor defect on paying the contract price for one time step.

[1] The NetLogo simulation is available from http://www.verwaart.nl/ValueChainLab

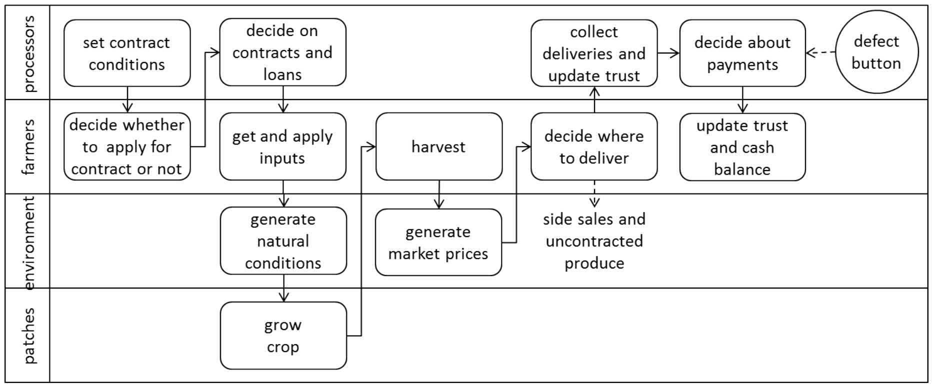

Fig. 2. Process overview of a time step representing a cropping season

Design concepts. The simulation is based on data collected in interviews with stakeholders during a value chain mapping activity as part of the 2Scale project assessment.

Basic principles: Crop growth depends on natural conditions and on quality of inputs and farmers' skills. Farmers base their decisions whether to invest in high quality inputs and skills, and enter into contracts or not, on information they get from the 2Scale programme and on personal characteristics of risk aversion an trust. Evaluation of risky alternatives is modeled using risk-averse utility functions of the form $U(r) = 1 - e^{-\lambda r}$, where λ represents an agent-specific risk aversion parameter and r some return. Trust is expressed as a real variable on the interval [0, 1], where 1 represents the belief that the other party will certainly comply, 0 represents the belief that the other will certainly defect, and 0.5 represents full uncertainty. Similarly, honesty is a personal characteristic of farmers which expresses the probability that they will not defect on a contract and side-sell when another buyer offers a price exceeding the contract price.

Emergence: Key observable outputs are the number of contracts, contracted area, harvested volume, volume delivered on contract, side-selling due to financial need, side-selling due to opportunism, farmers' gross revenue, and evolution of trust levels.

Adaptation: Agents increase trust when others comply and decrease it if they defect.

Objectives: The processor aims to contract as many farmers as possible; there is unfilfilled demand for local sorghum in Kenya. The farmers optimise on expected utility.

Stochasticity: Variation of outcomes results from the randomly drawn natural conditions and market prices, and from the side-selling behaviours where opportunities occur at random and honesty is modelled as a probability that a farmer will side-sell.

Initialization: The simulation is initialized with data gathered in the value chain mapping and in the games played with farmer groups. Parameters and sources of their values are documented in the NetLogo code[1] and summarized in Table 4. The farmers' characteristics measured in the games are summarized at the end of the present section.

Submodels. For a farmer with a risk-averse utility $U(r) = 1 - e^{-\lambda r}$, where λ stands for constant absolute risk aversion (CARA) and r for the return from one cropping season, the expected utility of selling the produce on the market after harvest is computed as

$$\mathrm{E}(U_{\text{market}}) = \frac{1}{u-l}\int_l^u 1 - e^{-\lambda r}\,\mathrm{d}r = 1 + \frac{e^{-\lambda u} - e^{-\lambda l}}{(u-l)\lambda}, \tag{1}$$

where r is assumed uniformly distributed between lower limit l and upper limit u. A fixed-price contract may be attractive, but a farmer may be uncertain whether the processor will comply with the contract if market prices turn out to be less than the contract price. Defining trust t as a farmer's subjective belief of the probability that the processor will comply, the expected utility of selling on a contract with return c is

$$\mathrm{E}(U_{\text{contract}}) = \frac{u-c}{u-l}(1-e^{-\lambda c}) + \frac{c-l}{u-l}\left(t(1-e^{-\lambda c}) + (1-t)\left(1 + \frac{e^{-\lambda c} - e^{-\lambda l}}{(c-l)\lambda}\right)\right). \tag{2}$$

Farmers decide to apply for a contract if $\mathrm{E}(U_{\text{contract}}) > \mathrm{E}(U_{\text{market}})$. A processor agent rejects a contract application if its experience-based trust in the farmer is less than 0.5.

Farmer groups apply for loans if a majority of the members are contracted and all menbers have group trust greater than 0.5. In that case, group members stand surety for each other, the loan is granted, and all group members are contracted.

Farmers can deliver their produce in several ways. First, with some probability that can be set in the user interface, a travelling aggregator may pass by just in time after the harvest and offer the current market price. Farmers can then deliver without transaction cost. A farmer who has no contract wil sell the total harvest. A contracted farmer who is broke will side-sell part of the harvest. In addition, farmers may consider to side-sell if the market price is more than the expected contract revenue; in the simulation they decide to do so with probability $(1-h)$, where h represents a farmer's honesty. If no aggregator passes by, a farmer in financial need must sell part of the harvest for a low price on the local market. Farmers without contract sell on the spot market, but now with transaction cost. Contracted farmers deliver the remaining harvest to the processor.

Processors keep records of received deliveries and pay the farmers, after subtracting the loans, costs of loan and insurance, and sureties for defecting group members, when applicable. Based on natural conditions and inputs used, processors estimate the potential deliveries from contracted farmers and pay a bonus to groups who have complied.

Farmers' trust in processors, processors' trust in farmers and farmers' group trust are updated in each time step s according to slow positive, fast negative dynamics [10]:

$$t_{s+1} = \begin{cases} t_s + d_{\text{pos}}(1-t_s) & \text{if the other party complied} \\ t_s - d_{\text{neg}}\,t_s & \text{if the other party defected} \end{cases}, \tag{3}$$

where the update factors $0 < d_{\text{pos}} < d_{\text{neg}} < 1$ are agent properties.

Agent characteristics with respect to trust, honesty, and risk attitude can be initialized, at the users' choise, by random generation from ranges specified by the user, or by random drawing from the results of the games played in Kenya.

Game results for trust and honesty. Farmer's *trust in the sorghum processor* of the 2SCALE initiative was measured in a trust game. 60 Farmers who had at least for 1 season delivered sorghum to this processor were told they were sending their coins to this processor. Trust was measured as the relative amount of coins sent to the processor

Table 1. Farmers' trust in the 2SCALE processor and in their groups and farmer's honesty levels

Trust/honesty level[a]	0.0	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	1.0
Processor trust level frequency	4	1	3	0	2	5	3	7	18	10	27
Group trust level frequency	13	1	4	18	18	28	20	15	10	6	11
Farmer honesty frequency	5	7	18	11	8	29	7	8	9	4	38

[a] Since the initial endowment was 10 coins, levels range from 0.0 to 1.0 in steps of 0.1.

compared to the initial endowment of 10 coins. Farmer's *trust in the fellow group members* was measured in a trust game with 144 farmers who had delivered to the 2SCALE processor for 1 season at least. Trust was measured as the relative amount of coins compared to the initial endowment of 10 coins sent to another group member. Farmer's *honesty* was measured as the relative amount of coins compared to the initial endowment of 10 coins send to the public account in a VCM game played with the same 144 farmers who played the group trust game. Table 1 provides the observed frequencies of trust in the processor, group trust, and honesty.

Trust update was measured in a repeated trust game where 240 farmers were told they were sending their coins to a new sorghum buyer in town. The 240 farmers included 144 farmers delivering sorghum to the 2SCALE processor and 96 farmers who did not. The game was repeated 3 times. The trust update was a farmer's trust level in game $t+1$ minus the level in game t. We used the trust update from the second to the third trust game, because the results could be influenced by learning. Of the farmers, 25% received as return half the amount they send to the new buyer, 25% the amount, 25% one and a half times the amount, and the last 25% double the amount. The first group had a negative experience, so their trust updates were considered as negative update factors. The last group had a positive experience, so their trust update were considered as positive update factors. Table 2 shows the frequencies of the trust dynamics.

Table 3 shows results of the *risk perception game* for the 182 farmers (out of 240) who showed consistent risk perception results. Farmers who choose the certain option in a game with a specific certain amount and the gamble option in a game with a higher certain amount, and farmers who switched multiple times between the options were excluded from this analysis. Farmers were divided into groups, depending on the game at which they switched from gamble to certain. To estimate relative risk aversion α for each group, the exponential utility function $U(r) = 1 - e^{-\alpha r}$ was used. For example for the "Certain from 10 to 60 KES" group, the utility of getting 10 KES for certain was set equal to that of the gamble: $U(10/60) = 0.5U(60/60) + 0.5U(0/60)$.

Table 2. Trust update factors measured in the repeated trust game

Update factor	-0.5	-0.3	-0.2	-0.1	0.0	0.1	0.2	0.3	0.4	0.5	0.7
Negative update frequency	4	5	5	14	19	6	2	1	1	2	1
Positive update frequency		1	1	6	30	10	10	2			

Table 3. Results from the risk perception game

Description group	Frequency	Relative risk aversion
Certain from 10 to 60 KES	111	3.72
Gamble at 10 KES, certain from 20 to 60 KES	19	1.86
Gamble from 10 to 20 KES, certain from 30 to 60 KES	13	1.24
Gamble from 10 to 30 KES, certain from 40 to 60 KES	12	0.93
Gamble from 10 to 40 KES, certain from 50 to 60 KES	8	0.74
Gamble from 10 to 50 KES, certain at 60 KES	8	0.62
Gamble from 10 to 60 KES	11	

5 Results

The agent-based simulation is initialized with data collected in a value chain mapping mission, a baseline survey for the quantitative evaluation of 2SCALE, and games played with farmer groups in Kenya. Simulations are run for a period of 20 growing seasons seasons (10 years). Table 4 displays the default parameter settings. The "savings" switch is by default set to false: farmers are assumed to spend their all revenue from a harvest during the following growing season on inputs for the next harvest and on cost of living. Farmers' characteristics can be intitialized in two ways. By default, risk aversion, initial trust, trust update, and honesty are drawn from the specified ranges and the specified trust update factors are applied. When the "configure-from-game-data" switch is true, the parameter values are drawn at random from the game outcomes. Emergent properties to be observed are farm income and the availability of sorghum to the processor.

Table 4. Default parameter settings

Parameter	Value	Unit	Parameter	Value	Unit
Farms	9216		minimal-natural-conditions	0.5	
minimal-farmgate-price	14000	KES/ton	savings	false	
maximal-farmgate-price	30000	KES/ton	minimal-risk-aversion[b]	5.0E-5	1/KES
local-market-price	14000	KES/ton	maximal-risk-aversion	2.0E-4	1/KES
aggregator-availability	20	%	minimal-initial-trust	0.2	
optimal-inputs-cost	14000	KES/ha	maximal-initial-trust	1.0	
labour-cost	22000	KES/ha	minimal-honesty	0.2	
loan-per-ha	30000	KES/ha	maximal-honesty	1.0	
cost-loan&insurance	5000	KES/ha	configure-from-game-data	false	
post-harvest-cost-per-ton	2900	KES/ton	to-be-delivered	5000	ton
transaction-cost-market	1000	KES	farmers-contract-price	25000	KES/ton
transaction-cost-contract	0	KES	maximal-group-bonus	2000	KES/ton
basic-expected-yield	1.2	ton/ha	bonus-lower-bound	80	%
improved-inputs-yield	5.0		positive-trust-update-factor	0.05	
minimal-skills-factor	0.0		negative-trust-update-factor	0.10	

[b] Relative risk aversion assumed in range [1, 4], amount at stake 20000 KES

Table 5. Average outcomes for first 4 and last 4 seasons of a 10-year period, for 30 runs with farmer agents configured with game data ("configure-from-game-data"=TRUE) versus 30 runs with default settings ("configure-from-game-data"=FALSE)

Emergent outcome	first 4 seasons Game data	Default	last 4 seasons Game data	Default
mean total harvest (tons)	11832	12297	10362	9910
mean number of loans	3003	4917	1363	8
mean number of contracts	8765	9204	3679	3775
mean total contract deliveries (tons)	7667	8979	6840	7843
mean total side-sales to aggregators (tons)	3027	2727	948	953
mean total side-sales in local markets (tons)	665	591	59	40
mean gross margin (KES/farmer)	18576	21179	17852	15629

Table 5 presents outcomes with game data and outcomes with default parameters. Data are comparable, except for the stronger decay of the number of loans in the runs with default parameters; the agents with zero trust-update in the game-configured runs maintain their group trust even if group members defect (cf. Table 2). Dynamics of some outcomes are shown in Fig. 3. Initially farmers enter into contracts and groups apply for loans. Then the number of loans decreases and after that the number of contracts. As can be seen from the righthand graphs, in particular the less productive farmers lose their contracts. Fig. 4 provides insight into the causes. The middle graph shows side-selling. Farmers side-sell when in urgent need for cash. Group members, who stand surety, must redeem their loans, lose trust in the group, and no longer apply for loans.

Fig. 3. Dynmics of some emergent outcomes from a simulation configured with default settings (upper row) and a run with game-based settings (bottom row)

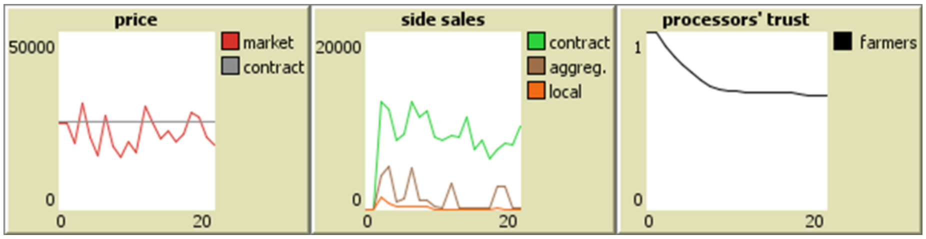

Fig. 4. Causes of the decline of loans and contracts (game-based settings)

The middle graph also shows opportunistic side-sales by contracted farmers under high market prices (cf. left-hand graph), continuing after the loans system has collapsed. The defecting farmers lose the processors' trust (cf. right-hand graph) and contracts.

The results show a decline in harvest volumes and deliveries on contracts over the simulated period, but not to an extent that the processor can not fulfil its current contract. However, many farmers remain poor and there is no room to satisfy new demands. Sensitivity analysis of the simulation may identify promising interventions. The most promising could be to improve the weaker producers' skills (see Table 6). The sensitivity analysis also shows that a 1000 KES lower contact price of 2400 KES strongly affects deliveries to the producer (-11%), side-sales (from 10 to 13%), and farmers' gross margins (-10%). Lower honesty has an effect of +13% on gross margins, but affects deliveries with -16%. As may be expected,variations in the trust parameters affect outcomes up to 10%. In the present setting, sensitivity to risk attitude is weak, but it is stronger with lower contract prices. More sensitivity data are available on the web[1].

6 Discussion

Results of the simulation runs showed it is essential for a stable contract supply with farmers income being higher than without contracts, that the sorghum processor provides a stable and high contract price against uncertain alternatives for farmers. Another key to long-run success of the system is the extent to which individual farmers can be convinced to comply, even when market prices are high. Finally, improving farmers

Table 6. Average outcomes for last 4 seasons of a 10-year period of simulations with improved skills (”minimum-skills”=0.5; mean outcomes of 30 runs)

Outcome	Harvest	#Loans	#Contracts	Delivery	Gross margin
With default parameters	9910	8	3775	7843	15629
– With minimal skills = 0.5	18535	3921	7912	15860	36469
– Increase (%)	87	–	110	102	133
With game data	10362	1363	3679	6840	17852
– With minimal skills = 0.5	18137	2318	5994	12923	33496
– Increase (%)	75	70	63	89	88

skills is an effective way to increase total sorghum production and volume supplied to the processor. Such insights are useful for the processor to develop its long-term policy and for the 2SCALE programme to develop its intervention policy.

Data about trust, trust development, honesty and risk attitude of sorghum farmers in the Meru region in Kenya were not available in literature. Therefore, we used trust, VCM, and risk preference games with a selected number of sorghum farmers to gather these data. We could not compare these to trust, honesty, and risk attitude of other sorghum farmers in Kenya, because country wide data was lacking. Thus, results can be seen representative for the farmers participating in the games. Gathering more data of farmers in other regions, can provide insight into the extrapolation potential of the results of this study. Model results were validated by checking the correctness of the equations in the model and if the results could be explained rationally.

With the model the impact can be estimated of alternative intervention strategies, such as an incentive system for sorghum quality. Ranking these strategies in increasing effectiveness, e.g. farmer income or total supply chain profit, can aid in designing effective intervention strategies prior to implementation. Thus, the model can aid in decreasing failure costs of interventions in sorghum production in Kenya. However, the model can be adapted to other commodities and other countries where trust between farmers and processors and mutual trust within the groups play important roles in the supply chain. In this way, the model is a valuable tool for analysing inclusive business approaches in development aid programs.

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