New McDonald had a farm
A computational model of farming decision making

Claudius Gräbner*[1], Merritt Hughes†[2], and Martin Smyth‡[3]

[1]Institute for Institutional and Innovation Economics, University of Bremen, Germany.

[2]University of Massachusetts, Boston.

[3]Stony Brook University, Stony Brook, NY.

June 30, 2016

1 Introduction

In this paper, we construct a sequence of computational models to study the strategic decision-making of agricultural producers (farmers) with respect to their means of production. For the sake of concreteness we first construe our means of production as seed stock having either proprietary (P) or non-proprietary (NP) genetic composition.

The results can, however, be generalized fairly easily. We therefore anticipate our model to have direct application to various important policy areas. The main goal of our research is to identify impact of individual decision-making on both individual and societal outcomes. Although developed to address agricultural production decisions (e.g., those arising from Monsanto's introduction of proprietary maize in Mexico), lessons drawn from our model can also be applied in other areas as well. Assessing the relative societal gains of proprietary versus open-source software development strategies is only one example for such further applications.

More concretely, our model is constructed to answer the following three research questions:

*graebnerc@uni-bremen.de
†merritth@wanadoo.fr
‡martin.smyth@stonybrook.edu

(0.)	(Only in t_0: Initialization of the population and spatial allocation of the farmers.)
1.	Calculation of the mean yield for the NP farmers (not in t_0).
2.	Farmers choose their seed type sequentially (in a randomly determined sequence).
3.	Recording of all relevant state variables.

Table 1: The sequence of events in the simulation.

1. How are societal crop yields impacted by individual farmers' production decisions?

2. What are the aggregate group yields of farmers using proprietary versus non-proprietary seed?

3. Do the proportions of farmers using each type of seed reach stable equilibria?

The rest of the article is structured as follows:

Section 2 introduces our computational model and section A presents the results. Then section 4 summarizes the paper and gives an outlook on future research.

2 Model description

We first build a very primitive and simple model for the problem at hand. We then add more complex decision making rules for the agents. This allows us the isolate the systemic effects of the changes in individual decision making.

All implementations of the model follow the same sequence of events, as illustrated in table 1. Agents first make a decision which seed to use. The decision making procedure depends on the model specification. At the end of the time step, agents receive their payoff according to the procedure mandated by the particular model specification.[1]

2.1 Baseline model

We have a number of N farmers, each of which needs to choose between the proprietary and non-proprietary seed. In the baseline model, agents choose the seed randomly according to a probability fixed as a parameter p_P. At the end of each time step, agents receive their payoffs. The yield of the P seed is fixed (and known to every agent) at Y_P. The yield of the NP seed is stochastic at the individual level following a truncated normal distribution with mean Y_P and given variance σ^2 over the positive reals.

[1] We will keep the model description short. The source code is freely available at https://github.com/graebnerc/New-McDonald.

2.2 Model extension 1

In the first extension we relax the assumption of random choice of seed. Rather, agents compare the yield of the two seed types in previous time steps and pick those with the higher value. There are basically three different implementations of this and we explore all of them in our model:

1. The agents compare the fixed return of the proprietary seed with the average yield of all agents that have used the non-proprietary alternative in the last k rounds (k is a parameter).

2. The agents are located on a grid (with a von Neumann neighborhood) and compare the P payoff with the average payoffs of their neighbors using the NP seed (again considering the previous k rounds).

3. This case does not differ to case B, but agents put more weight on their own payoff in the previous round (with a 50 per cent) weight.

In any case, we introduce a parameter k which specifies the memory of the farmers (i.e. the number of previous time steps they consider for the calculation of past yields.[2]

2.3 Model extension 2

The second extension allows for network effects of the NP seed. The expected yield is now a function of the number of agents using this seed. If Y_P and Y_{NP} denotes the yield of the P and NP seed respectively, n is the number of farmers currently using the NP seed, and N the total number of farmers, we have the following expression:

$$Y_{NP} = Y_P \frac{n}{N} \tag{1}$$

The rationale behind this is the increasing potential for innovation in such an “open source” environment.[3]

3 Results

We run the model for 100 times and analyzed the mean, standard variation, and the 90 and 10 per cent interval of the results.

[2]This means that if $k = 1$ farmers only compare the yields of the previous round. If $k = 10$ they compare the average yield over the past 10 periods.

[3]In future work, this mechanism could be modeled explicitly using a genetic algorithm searching the space of possible seeds.

The yields for P farmer group are given by a parameter Y_P, yet some variation enters the results due to variations in the number of farmers choosing this technology, n_P.

For the NP group, variation in yields is the result of both variation in individual farmers' yields (which depends on the parameter σ_{NP} and variation of the number of farmers in the group. Therefore, variation of the two groups is equal if $\sigma_{NP} = 0$. You may verify this by looking at tables 2-13 in the appendix which summarize the data generated by our model.

Note that at a first glance holding farmers' probability of switching strategies at a constant value while increasing stochastic variation in NP yields seems to increase societal yields (see Tables $2 - 5$). But since the standard deviation is much higher than the difference in means, this is due to random fluctuations in the different model iterations.

The results of the baseline model are illustrated in figure 1. The graph depicts the results for $p_P = 0.5$ and $\sigma_{NP} = 10$ over an interval of 100 time steps. We observe that total returns randomly fluctuate around the mean and the shares of the two seed types fluctuate around p_P and $1 - p_P$ verifies the functioning of our model.

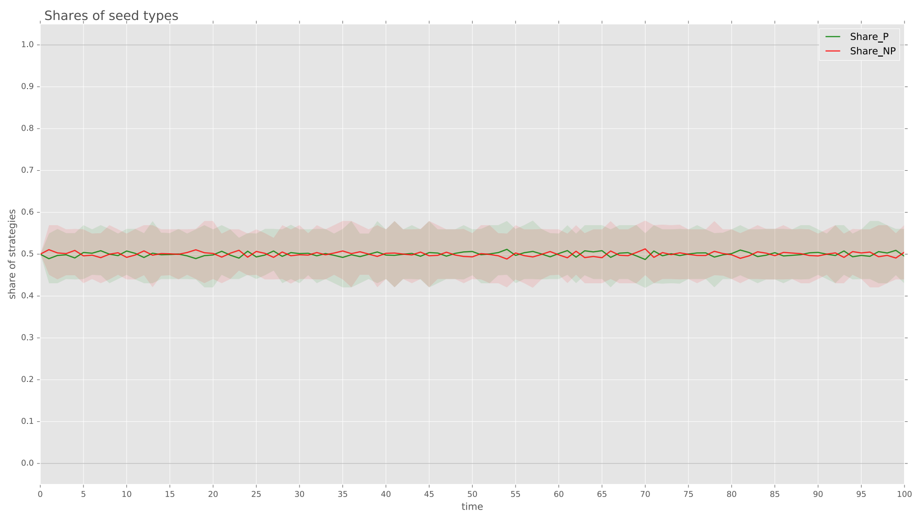
The fact that the output of our baseline model generally corresponds to what we expected from our model specification, serving to validate our model formulation.

This allows us to explore more complex decision making procedures for the farmers and isolate their effects on the system as a whole.

The first extension we made was that farmers could chose the seed with the highest expected yield based on one of a number of retrospective comparisons.

In the current model formulation, it appears that the parameter k (which specifies the look-back period for yield evaluation and strategy evaluation) influenced the evolution of the model results. The longer the look-back interval (higher values of k) for both Case A and B, the longer was the adjustment period. Figure 2, illustrates the difference for case A (the dynamics is similar to case B).

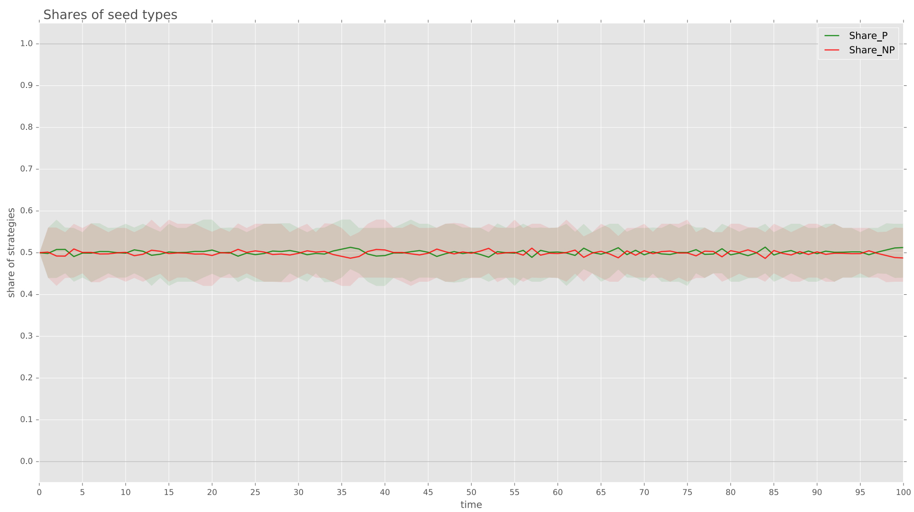
The second extension we made to the model was to make the expected yield of NP dependent on the fraction of farmers choosing NP. Because the NP yield was based on the number of participants, variation in yield was greater in those situations where farmers based their decision to switch on the yields of all NP farmers (see Figure 3a). This contrasts remarkably with Case B (Figure 3b), where farmers only



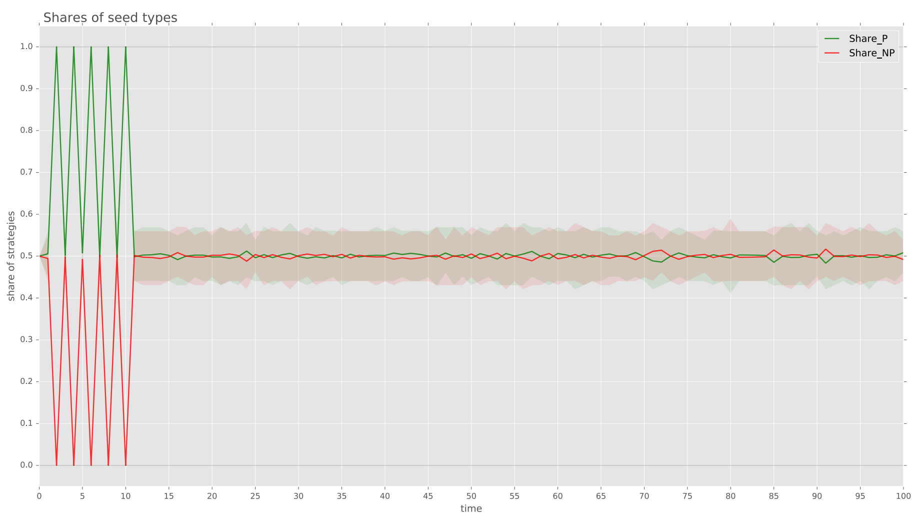
(a) Group shares.

(b) Group yields.

Figure 1: Results for the baseline model with $p_P = 0.5$ and $\sigma_{NP} = 10$. The model was run for 100 times, shaded area illustrates 10 and 90 per cent intervals of the results.

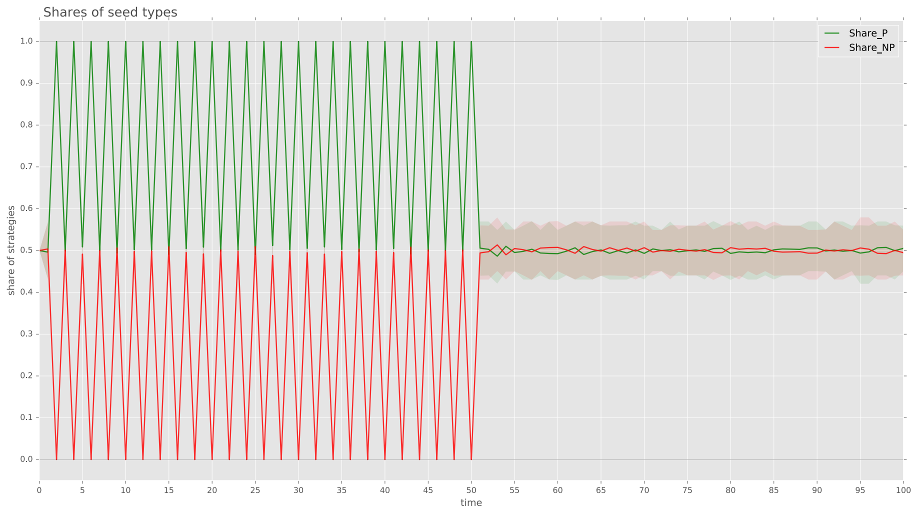


(a) Result for decision making case A and $k = 1$.

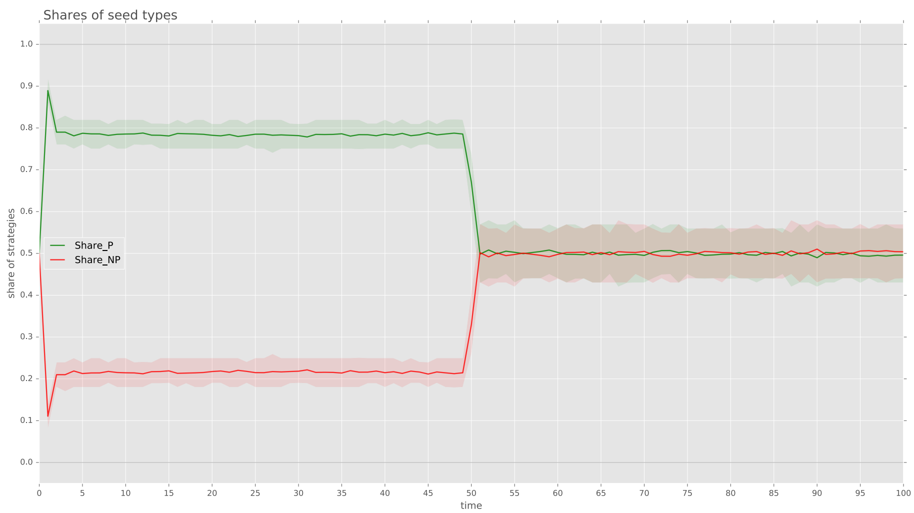


(b) Result for decision making case A and $k = 10$.

Figure 2: Results for the first model extension.



(a) Result for decision making case A and $k = 50$ when farmers take the return of all NP farmers into account.



(b) Result for decision making case B and $k = 50$ when farmers take the return of all NP farmers in their neighborhood into account.

Figure 3: Results for the second model extension.

observed the yields of their immediate neighbors.

4 Conclusion

We introduced a model of agricultural production in which producers (farmers) choose between proprietary (P) and non-proprietary (NP) seed stocks. We apply our model to assess the aggregate societal and group yields resulting from farmers' decisions, and the market penetration of each seed stock.

In our baseline model, farmers' decision-making is random. This simple baseline scenario allowed us to isolate the effect of changes in the farmers decision making process on systemic dynamics. In our first model extension, farmers' decision-making is informed by their observation of P and NP yields over preceding time intervals. In our second extension, the yields of NP seeds increase with increased NP seed adoption, while P seed yields remain fixed. As we introduce retrospective decision-making, we observe that the look-back parameter k influences the evolution of the model results.

Farmers' learning intervals were extended with increasing values of k (i.e., longer the look-back intervals). Where farmers place greater weight on their own yields, the system becomes easily locked into the NP strategy. When NP yields were determined by the rate of NP seed adoption, we observed that variation in yields was greater where farmers based their decision to switch on the yields of all NP farmers. Variation in yields was reduced where farmers observed only their immediate neighbors.

Although our model addresses agricultural production, our model formulation can also be applied to investigate the systemic effects of individuals' decisions vis-à-vis other technologies (e.g., the societal value of proprietary versus open-source technological innovation), or between differing social, political or economic institutions. The model may also be extended to study the mechanisms underlying the network effects we assumed for the NP seed in the second model extension: we could model the evolution of the seed via a genetic algorithm and elaborate on the time scale required for superior seeds to be developed. This may entail important policy implications with direct applications to a number of real world scenarios.

Another direction of further research would be to assume a homogeneous, non-structured population with random interactions and use evolutionary game theory and replicator dynamics to explore systemic outcomes. While assuming away some distinctive aspects of reality, such a model specification would allow for an analytical treatment of the system and provide a good starting point for further computational analysis.

A Results for the baseline model

	mean	sd	10% quant	90% quant
Total_return	200.00	0.00	200.00	200.00
Returns_P	100.24	11.69	84.00	114.40
Returns_NP	99.76	11.69	85.60	116.00
Returns_P_pc	2.00	0.00	2.00	2.00
Returns_NP_pc	2.00	0.00	2.00	2.00
Share_P	0.50	0.06	0.42	0.57
Share_NP	0.50	0.06	0.43	0.58

Table 2: Summary statistics for baseline model with switching probability 50% and $\sigma_{NP} = 0$.

	mean	sd	10% quant	90% quant
Total_return	200.63	5.49	193.59	206.34
Returns_P	99.92	10.14	88.00	112.00
Returns_NP	100.71	11.26	88.95	117.08
Returns_P_pc	2.00	0.00	2.00	2.00
Returns_NP_pc	2.01	0.11	1.86	2.14
Share_P	0.50	0.05	0.44	0.56
Share_NP	0.50	0.05	0.44	0.56

Table 3: Summary statistics for baseline model with switching probability 50% and $\sigma_{NP} = 1$.

	mean	sd	10% quant	90% quant
Total_return	205.52	30.79	170.12	246.75
Returns_P	101.30	9.73	89.80	112.20
Returns_NP	104.22	32.50	68.72	153.30
Returns_P_pc	2.00	0.00	2.00	2.00
Returns_NP_pc	2.11	0.63	1.37	2.98
Share_P	0.51	0.05	0.45	0.56
Share_NP	0.49	0.05	0.44	0.55

Table 4: Summary statistics for baseline model with switching probability 50% and $\sigma_{NP} = 5$.

	mean	sd	10% quant	90% quant
Total_return	203.98	56.60	136.18	271.49
Returns_P	99.00	10.72	85.80	112.20
Returns_NP	104.98	56.06	40.22	179.03
Returns_P_pc	2.00	0.00	2.00	2.00
Returns_NP_pc	2.10	1.13	0.79	3.44
Share_P	0.50	0.05	0.43	0.56
Share_NP	0.50	0.05	0.44	0.57

Table 5: Summary statistics for baseline model with switching probability 50% and $\sigma_{NP} = 10$.

	mean	sd	10% quant	90% quant
Total_return	200.00	0.00	200.00	200.00
Returns_P	49.04	7.50	40.00	58.20
Returns_NP	150.96	7.50	141.80	160.00
Returns_P_pc	2.00	0.00	2.00	2.00
Returns_NP_pc	2.00	0.00	2.00	2.00
Share_P	0.25	0.04	0.20	0.29
Share_NP	0.75	0.04	0.71	0.80

Table 6: Summary statistics for baseline model with switching probability 25% and $\sigma_{NP} = 0$.

	mean	sd	10% quant	90% quant
Total_return	200.68	8.06	190.66	211.50
Returns_P	47.90	8.11	38.00	58.00
Returns_NP	152.78	11.05	137.72	165.00
Returns_P_pc	2.00	0.00	2.00	2.00
Returns_NP_pc	2.01	0.11	1.88	2.14
Share_P	0.24	0.04	0.19	0.29
Share_NP	0.76	0.04	0.71	0.81

Table 7: Summary statistics for baseline model with switching probability 25% and $\sigma_{NP} = 1$.

	mean	sd	10% quant	90% quant
Total_return	194.90	33.05	155.39	239.87
Returns_P	49.62	8.82	40.00	60.00
Returns_NP	145.28	32.73	107.49	188.42
Returns_P_pc	2.00	0.00	2.00	2.00
Returns_NP_pc	1.94	0.44	1.42	2.54
Share_P	0.25	0.04	0.20	0.30
Share_NP	0.75	0.04	0.70	0.80

Table 8: Summary statistics for baseline model with switching probability 25% and $\sigma_{NP} = 5$.

	mean	sd	10% quant	90% quant
Total_return	191.16	74.29	104.91	283.52
Returns_P	48.82	8.33	38.00	58.00
Returns_NP	142.34	76.87	60.64	236.92
Returns_P_pc	2.00	0.00	2.00	2.00
Returns_NP_pc	1.87	0.99	0.76	3.11
Share_P	0.24	0.04	0.19	0.29
Share_NP	0.76	0.04	0.71	0.81

Table 9: Summary statistics for baseline model with switching probability 25% and $\sigma_{NP} = 10$.

	mean	sd	10% quant	90% quant
Total_return	200.00	0.00	200.00	200.00
Returns_P	149.84	9.58	138.00	162.00
Returns_NP	50.16	9.58	38.00	62.00
Returns_P_pc	2.00	0.00	2.00	2.00
Returns_NP_pc	2.00	0.00	2.00	2.00
Share_P	0.75	0.05	0.69	0.81
Share_NP	0.25	0.05	0.19	0.31

Table 10: Summary statistics for baseline model with switching probability 75% and $\sigma_{NP} = 0$.

	mean	sd	10% quant	90% quant
Total_return	199.27	4.31	193.31	204.50
Returns_P	150.10	8.81	138.00	162.00
Returns_NP	49.17	9.66	37.24	61.02
Returns_P_pc	2.00	0.00	2.00	2.00
Returns_NP_pc	1.97	0.17	1.75	2.18
Share_P	0.75	0.04	0.69	0.81
Share_NP	0.25	0.04	0.19	0.31

Table 11: Summary statistics for baseline model with switching probability 75% and $\sigma_{NP} = 1$.

	mean	sd	10% quant	90% quant
Total_return	197.21	24.03	167.03	226.01
Returns_P	151.76	8.09	142.00	162.00
Returns_NP	45.45	24.36	14.63	75.52
Returns_P_pc	2.00	0.00	2.00	2.00
Returns_NP_pc	1.89	1.00	0.59	3.20
Share_P	0.76	0.04	0.71	0.81
Share_NP	0.24	0.04	0.19	0.29

Table 12: Summary statistics for baseline model with switching probability 75% and $\sigma_{NP} = 5$.

	mean	sd	10% quant	90% quant
Total_return	200.82	39.80	149.52	253.99
Returns_P	148.86	7.54	139.80	158.00
Returns_NP	51.96	40.81	-2.26	102.25
Returns_P_pc	2.00	0.00	2.00	2.00
Returns_NP_pc	2.03	1.61	-0.10	3.80
Share_P	0.74	0.04	0.70	0.79
Share_NP	0.26	0.04	0.21	0.30

Table 13: Summary statistics for baseline model with switching probability 75% and $\sigma_{NP} = 10$.

B Results for extension 1

	mean	sd	10% quant	90% quant
Total_return	200.00	0.00	200.00	200.00
Returns_P	102.50	10.34	88.00	114.00
Returns_NP	97.50	10.34	86.00	112.00
Returns_P_pc	2.00	0.00	2.00	2.00
Returns_NP_pc	2.00	0.00	2.00	2.00
Share_P	0.51	0.05	0.44	0.57
Share_NP	0.49	0.05	0.43	0.56

Table 14: Summary statistics for extension one with $k = 1$, $\delta_P = 50\%$, and decision making A.

	mean	sd	10% quant	90% quant
Total_return	200.00	0.00	200.00	200.00
Returns_P	99.62	9.95	88.00	112.00
Returns_NP	100.38	9.95	88.00	112.00
Returns_P_pc	2.00	0.00	2.00	2.00
Returns_NP_pc	2.00	0.00	2.00	2.00
Share_P	0.50	0.05	0.44	0.56
Share_NP	0.50	0.05	0.44	0.56

Table 15: Summary statistics for extension one with $k = 1$, $\delta_P = 50\%$, and decision making B.

	mean	sd	10% quant	90% quant
Total_return	200.0	0.0	200.0	200.0
Returns_P	0.0	0.0	0.0	0.0
Returns_NP	200.0	0.0	200.0	200.0
Returns_P_pc	0.0	0.0	0.0	0.0
Returns_NP_pc	2.0	0.0	2.0	2.0
Share_P	0.0	0.0	0.0	0.0
Share_NP	1.0	0.0	1.0	1.0

Table 16: Summary statistics for extension one with $k = 1$, $\delta_P = 50\%$, and decision making C.

C Results for extension 2

	mean	sd	10% quant	90% quant
Total_return	200.00	0.00	200.00	200.00
Returns_P	101.68	9.00	92.00	112.00
Returns_NP	98.32	9.00	88.00	108.00
Returns_P_pc	2.00	0.00	2.00	2.00
Returns_NP_pc	2.00	0.00	2.00	2.00
Share_P	0.51	0.04	0.46	0.56
Share_NP	0.49	0.04	0.44	0.54

Table 17: Summary statistics for extension one with $k = 10$, $\delta_P = 50\%$, and decision making A.

	mean	sd	10% quant	90% quant
Total_return	200.00	0.00	200.00	200.00
Returns_P	99.58	10.55	88.00	112.00
Returns_NP	100.42	10.55	88.00	112.00
Returns_P_pc	2.00	0.00	2.00	2.00
Returns_NP_pc	2.00	0.00	2.00	2.00
Share_P	0.50	0.05	0.44	0.56
Share_NP	0.50	0.05	0.44	0.56

Table 18: Summary statistics for extension one with $k = 10$, $\delta_P = 50\%$, and decision making B.

	mean	sd	10% quant	90% quant
Total_return	200.0	0.0	200.0	200.0
Returns_P	0.0	0.0	0.0	0.0
Returns_NP	200.0	0.0	200.0	200.0
Returns_P_pc	0.0	0.0	0.0	0.0
Returns_NP_pc	2.0	0.0	2.0	2.0
Share_P	0.0	0.0	0.0	0.0
Share_NP	1.0	0.0	1.0	1.0

Table 19: Summary statistics for extension one with $k = 10$, $\delta_P = 50\%$, and decision making C.

	mean	sd	10% quant	90% quant
Total_return	200.00	0.00	200.00	200.00
Returns_P	100.72	9.46	90.00	112.20
Returns_NP	99.28	9.46	87.80	110.00
Returns_P_pc	2.00	0.00	2.00	2.00
Returns_NP_pc	2.00	0.00	2.00	2.00
Share_P	0.50	0.05	0.45	0.56
Share_NP	0.50	0.05	0.44	0.55

Table 20: Summary statistics for extension one with $k = 50$, $\delta_P = 50\%$, and decision making A.

	mean	sd	10% quant	90% quant
Total_return	200.0	0.0	200.0	200.0
Returns_P	0.0	0.0	0.0	0.0
Returns_NP	200.0	0.0	200.0	200.0
Returns_P_pc	0.0	0.0	0.0	0.0
Returns_NP_pc	2.0	0.0	2.0	2.0
Share_P	0.0	0.0	0.0	0.0
Share_NP	1.0	0.0	1.0	1.0

Table 21: Summary statistics for extension one with $k = 50$, $\delta_P = 50\%$, and decision making B.

	mean	sd	10% quant	90% quant
Total_return	200.0	0.0	200.0	200.0
Returns_P	0.0	0.0	0.0	0.0
Returns_NP	200.0	0.0	200.0	200.0
Returns_P_pc	0.0	0.0	0.0	0.0
Returns_NP_pc	2.0	0.0	2.0	2.0
Share_P	0.0	0.0	0.0	0.0
Share_NP	1.0	0.0	1.0	1.0

Table 22: Summary statistics for extension one with $k = 50$, $\delta_P = 50\%$, and decision making C.

	mean	sd	10% quant	90% quant
Total_return	200.0	0.0	200.0	200.0
Returns_P	200.0	0.0	200.0	200.0
Returns_NP	0.0	0.0	0.0	0.0
Returns_P_pc	2.0	0.0	2.0	2.0
Returns_NP_pc	0.0	0.0	0.0	0.0
Share_P	1.0	0.0	1.0	1.0
Share_NP	0.0	0.0	0.0	0.0

Table 23: Summary statistics for extension one with $k = 100$, $\delta_P = 50\%$, and decision making A.

	mean	sd	10% quant	90% quant
Total_return	200.00	0.00	200.00	200.00
Returns_P	133.72	8.90	122.00	144.00
Returns_NP	66.28	8.90	56.00	78.00
Returns_P_pc	2.00	0.00	2.00	2.00
Returns_NP_pc	2.00	0.00	2.00	2.00
Share_P	0.67	0.04	0.61	0.72
Share_NP	0.33	0.04	0.28	0.39

Table 24: Summary statistics for extension one with $k = 100$, $\delta_P = 50\%$, and decision making B.

	mean	sd	10% quant	90% quant
Total_return	200.0	0.0	200.0	200.0
Returns_P	0.0	0.0	0.0	0.0
Returns_NP	200.0	0.0	200.0	200.0
Returns_P_pc	0.0	0.0	0.0	0.0
Returns_NP_pc	2.0	0.0	2.0	2.0
Share_P	0.0	0.0	0.0	0.0
Share_NP	1.0	0.0	1.0	1.0

Table 25: Summary statistics for extension one with $k = 100$, $\delta_P = 50\%$, and decision making C.

	mean	sd	10% quant	90% quant
Total_return	200.00	0.00	200.00	200.00
Returns_P	97.90	9.42	84.00	110.20
Returns_NP	102.10	9.42	89.80	116.00
Returns_P_pc	2.00	0.00	2.00	2.00
Returns_NP_pc	2.00	0.00	2.00	2.00
Share_P	0.49	0.05	0.42	0.55
Share_NP	0.51	0.05	0.45	0.58

Table 26: Summary statistics for extension two with $k = 50$ and $\delta_P = 25\%$.

	mean	sd	10% quant	90% quant
Total_return	200.00	0.00	200.00	200.00
Returns_P	97.90	9.42	84.00	110.20
Returns_NP	102.10	9.42	89.80	116.00
Returns_P_pc	2.00	0.00	2.00	2.00
Returns_NP_pc	2.00	0.00	2.00	2.00
Share_P	0.49	0.05	0.42	0.55
Share_NP	0.51	0.05	0.45	0.58

Table 27: Summary statistics for extension two with $k = 50$ and $\delta_P = 25\%$.

	mean	sd	10% quant	90% quant
Total_return	200.00	0.00	200.00	200.00
Returns_P	97.90	9.42	84.00	110.20
Returns_NP	102.10	9.42	89.80	116.00
Returns_P_pc	2.00	0.00	2.00	2.00
Returns_NP_pc	2.00	0.00	2.00	2.00
Share_P	0.49	0.05	0.42	0.55
Share_NP	0.51	0.05	0.45	0.58

Table 28: Summary statistics for extension two with $k = 50$ and $\delta_P = 25\%$.

	mean	sd	10% quant	90% quant
Total_return	200.00	0.00	200.00	200.00
Returns_P	97.90	9.42	84.00	110.20
Returns_NP	102.10	9.42	89.80	116.00
Returns_P_pc	2.00	0.00	2.00	2.00
Returns_NP_pc	2.00	0.00	2.00	2.00
Share_P	0.49	0.05	0.42	0.55
Share_NP	0.51	0.05	0.45	0.58

Table 29: Summary statistics for extension two with $k = 50$ and $\delta_P = 25\%$.

	mean	sd	10% quant	90% quant
Total_return	200.00	0.00	200.00	200.00
Returns_P	97.90	9.42	84.00	110.20
Returns_NP	102.10	9.42	89.80	116.00
Returns_P_pc	2.00	0.00	2.00	2.00
Returns_NP_pc	2.00	0.00	2.00	2.00
Share_P	0.49	0.05	0.42	0.55
Share_NP	0.51	0.05	0.45	0.58

Table 30: Summary statistics for extension two with $k = 50$, $\delta_P = 25\%$ and decision based upon comparison of all farmers' yield (case A).

	mean	sd	10% quant	90% quant
Total_return	200.00	0.00	200.00	200.00
Returns_P	101.06	8.94	90.00	112.00
Returns_NP	98.94	8.94	88.00	110.00
Returns_P_pc	2.00	0.00	2.00	2.00
Returns_NP_pc	2.00	0.00	2.00	2.00
Share_P	0.51	0.04	0.45	0.56
Share_NP	0.49	0.04	0.44	0.55

Table 31: Summary statistics for extension two with $k = 50$, $\delta_P = 50\%$ and decision based upon comparison of all farmers' yield (case A).

	mean	sd	10% quant	90% quant
Total_return	200.00	0.00	200.00	200.00
Returns_P	99.96	9.26	88.00	112.00
Returns_NP	100.04	9.26	88.00	112.00
Returns_P_pc	2.00	0.00	2.00	2.00
Returns_NP_pc	2.00	0.00	2.00	2.00
Share_P	0.50	0.05	0.44	0.56
Share_NP	0.50	0.05	0.44	0.56

Table 32: Summary statistics for extension two with $k = 50$, $\delta_P = 75\%$ and decision based upon comparison of all farmers' yield (case A).

	mean	sd	10% quant	90% quant
Total_return	200.0	0.00	200.00	200.00
Returns_P	101.0	9.71	89.80	114.00
Returns_NP	99.0	9.71	86.00	110.20
Returns_P_pc	2.0	0.00	2.00	2.00
Returns_NP_pc	2.0	0.00	2.00	2.00
Share_P	0.5	0.05	0.45	0.57
Share_NP	0.5	0.05	0.43	0.55

Table 33: Summary statistics for extension two with $k = 50$, $\delta_P = 25\%$ and decision based upon comparison of neighbors' yield (case B).

	mean	sd	10% quant	90% quant
Total_return	200.0	0.00	200.00	200.00
Returns_P	99.2	10.10	86.00	112.00
Returns_NP	100.8	10.10	88.00	114.00
Returns_P_pc	2.0	0.00	2.00	2.00
Returns_NP_pc	2.0	0.00	2.00	2.00
Share_P	0.5	0.05	0.43	0.56
Share_NP	0.5	0.05	0.44	0.57

Table 34: Summary statistics for extension two with $k = 50$, $\delta_P = 50\%$ and decision based upon comparison of neighbors' yield (case B).

	mean	sd	10% quant	90% quant
Total_return	200.00	0.00	200.00	200.00
Returns_P	101.40	10.94	85.80	114.20
Returns_NP	98.60	10.94	85.80	114.20
Returns_P_pc	2.00	0.00	2.00	2.00
Returns_NP_pc	2.00	0.00	2.00	2.00
Share_P	0.51	0.05	0.43	0.57
Share_NP	0.49	0.05	0.43	0.57

Table 35: Summary statistics for extension two with $k = 50$, $\delta_P = 75\%$ and decision based upon comparison of neighbors' yield (case B).