Appendix of Study 4

A.1 Information on mapped carrot breeding and seed producing organisations

Table A1: Overview of carrot breeders and seed producers

Type of organisation	Size of organisation	Seed markets	Position of interviewee
Shareholder-owned company	Large size, international	Non-organic, NCT	Head of vegetable breeding
Family-owned company	Large size, international	Non-organic, NCT, organic	Vegetable breeder
Family-owned company	Large size, international	Non-organic, NCT, organic	Head of organic programmes
Association	Small size, mostly national	Organic	Head of organisation
Shareholder-owned company	Small size, mostly national	Organic	Head of organisation, vegetable breeders
Association	Small size, mostly national	Organic	Head of organisation
Family-owned company	Large size, international	Non-organic, NCT, organic	Vegetable breeder
Shareholder-owned company	Large size, international	Non-organic, NCT, organic	No interview possible
Shareholder-owned company	Large size, international	Non-organic, NCT, organic	No interview possible

A.2 VAL-MAS model input and output parameters

Table A2: Overview of the input and output parameters of the VAL-MAS model according to value chain levels

	Inputs	Outputs
Breeding	Revenue per sold basic seed CT	Total breeding budget in €
	Revenue per sold basic seed NCT	Total sold basic seed CT
	Revenue per sold basic seed organic	Total sold basic seed NCT
	Revenue per sold basic seed organic cultivar	Total sold basic seed organic
	Constraint approximate market size	Total sold basic seed organic cultivar
Seed multiplication	Cost of seed multiplication per Mio seed NCT	Total sold seed NCT
	Cost of seed multiplication per Mio seed organic	Total sold seed organic
	Cost of seed multiplication per Mio seed organic cultivar	Total sold seed organic cultivar
	Revenue of seed multiplication per Mio seed NCT	Total gross margin for NCT and organic seed sales
	Revenue of seed multiplication per Mio seed organic	Total gross margin for organic cultivar seed sales
	Revenue of seed multiplication per Mio seed organic cultivar	
Farming	Available land in ha	Used land per crop in ha

Available labour in person-hours	Used labour per crop in person-hours
Available organic seed in Mio seed	Used NCT seed per carrot crop in Mio seed
Available organic seed of an organic cultivar in Mio seed	Used organic seed per carrot crop in Mio seed
Variable costs per crop and ha in €	Used organic seed from an organic cultivar per carrot crop in Mio seed
Labour requirements per crop and ha	Costs and revenues per crop in €
NCT seed costs in € per organic carrot crop and ha	Production amount per crop in tons
Organic seed costs in € per organic carrot crop and ha	
Organic seed costs in € from an organic cultivar costs per organic carrot crop and ha	
NCT seed requirement in Mio seed per organic carrot crop and ha	
Organic seed requirement in Mio seed per organic carrot crop and ha	
Organic seed requirement in Mio seed from an organic cultivar costs per organic carrot crop and ha	
Farm gate prices in € per ton	
Yields per crop in ton	

A.3 Analysis of a European survey among organic farmers on organic seed use to establish the innovativeness scores

A subsample of a European survey of 128 observations comprising those farms that produce vegetable in Germany, Netherlands, Switzerland, and Austria were analysed with regression analysis. We took these additional countries into account to obtain a sample size that could be analysed in a meaningful way. As these countries are all in Central Europe, we expect the observations to be rather homogeneous and valid for the countries in the analysis. Independent variables in the analysis were *education (*dummy, no education 0, education in farming 1)*, farm size in ha, country* (for correction, as we include other Central European countries to obtain the sample size), and *farm type* (dummy, arable=0, vegetable=1). The dependent variable was *organic seed use* per hectare per farm enterprise in % of the overall number of hectares. Descriptive statistics of the variables are listed in Table A3. The coefficients of the regression analysis are given in Table A4. The R-squared value of the regression is 0.2470. Based on the estimated coefficients and the three selected characteristics in the agent population, innovativeness scores were computed for all 100 farm agents. On that basis, the assignment to innovation segments was determined.

Table A3: Descriptive statistics of independent and dependent variables

Variable	Mean (Standard deviation)
Organic seed use (% of overall ha)	0.78 (0.29)
Farm size (ln[ha])	2.96 (1.96)
Farm type (vegetable=1)	0.54 (0.50)
Education (education in farming 1)	0.83 (0.37)

Table A4: Regression coefficients of different farm characteristics on *organic seed use per farm enterprise*

Variable	Coefficient	*p*-value
Farm size (ln[ha])	-0.066	0.000
Farm type (vegetable=1)	-0.134	0.063
Education (education in farming 1)	0.21	0.033
Constant	0.91	0.000

A.4 Specifications of a survey among organic carrot producers in Germany

We surveyed German organic carrot producers partly with the online tool Lime survey and partly via phone between January and July of 2019. The online survey was distributed through organic vegetable extension services and organic marketing organisations. We obtained 20 responses from organic carrot producers willing to take the survey. The results are not representative; however, a variety of distribution channels for sharing the survey were used, such as consultancies and a wide variety of marketing organisations. There is no apparent bias regarding organic seed or cultivar use (e.g. much more organic seed is used by the interviewed farmers than is likely to be observed in reality). The questions in the survey focused on organic carrot production in Germany, i.e. on crop rotations, used cultivars, and differences in production costs between organic carrots produced with organic seed, NCT seed, and organic cultivars, among other items. Furthermore, we included specific questions about the WTP for organic seed and cultivars.

A.5 Agent population verification

For the verification of the farming agent population, the original RDC data was compared with three different agent populations (generated with different seed values). Although the correlation coefficients are weaker with some variables from the agent, they were still judged to be sufficiently close to the original values. Most of the average values of the original data and the generated data are similar. The procedure to generate the agent population was thus accepted and applied. The data is listed in Table A5.

Table A5: Overview of RDC data and generated farm population characteristics

	RDC data	**Farm population data (average of 3 populations)**	**RDC data**	**Farm population data (average of 3 populations)**
	Correlation coefficient with total agricultural area (ha)		Mean	
Total farm area (ha)	0.94	0.74	59.4	55.06
Total agricultural area (ha)	1	1	42.36	40.19
Vegetable area (ha)	0.5	0.40	6.47	6.62
Winter wheat (ha)	0.77	0.42	7.51	12.54
Winter rye (ha)	0.7	0.51	3.23	8.53
Legumes (ha)	0.83	0.64	7.16	6.21
Beans (ha)	0.35	0.20	1.12	6.29
Avail. Personhours (hrs/yr)	0.26	0.36	4176.68	4479.16

A.6 Specification of an excess WTP

We integrated an excess WTP into the simulation model. The upper bound of the overall distribution of the excess WTP across the farm population was assumed to represent the upper bound of the innovator group. Similarly, the lower bound of the overall distribution represented the lower bound of the laggards group. The overall distribution was then divided into five overlapping symmetric triangular sub-distributions with the same width on the x-axis indicating the WTP. The modes, minima, and maxima can be found in Table A6. In the calibration process, the modes, minima, and maxima of the sub-distributions were simultaneously shifted in steps of 50 € to adapt the WTP distribution so that the model results in an organic seed use share equal to the observation level of 10 %. To verify if around 10 % organic seed is used, the actual values per farm agent were then randomly drawn from the triangular sub-distribution representing the farm agent's innovativeness class and the baseline model was solved.

Deviations of 1% in both ways were accepted, because the benchmark of 10 % organic seed use can vary to this extent. This procedure is inspired by the calibration process of PMP models, where usually cost functions are calibrated according to observed farm areas (Heckelei et al. 2012; Howitt 1995). The distribution of the excess WTP was calibrated in the baseline scenario with the production reserve factor 1.2 and tested with the baseline scenario with the production reserve factor 1.5. If approximately 10 % of organic farming agents adopted organic seed in the two baseline scenarios, the excess WTP was accepted. Calibration was conducted under changing farm-gate prices and yields at farm level, to take uncertainties of these parameters into account. The excess WTP was held constant over all scenarios as ceteris paribus analysis, so that the effects of the scenarios could be analysed without too many interactions with other effects.

Table A6: Initial distribution values of symmetric triangular distributions for WTP calibration

	Minimum	**Mode**	**Maximum**
Innovators	350	400	450
Early adopters	300	350	400
Early majority	250	300	350
Late majority	200	250	300
Laggards	150	200	250

The distribution across the agent population is shown in Figure A1. It reflects the means of WTP values that result from ten random seed values for the agent population, as part of the sensitivity analysis. The figure shows that the organic carrot producers' excess WTP for organic seed and cultivars is on average 45% of the NCT seed. Some farmers are even willing to pay more than 65% additionally. Farm-saved seed was disregarded in this case study, because German organic carrot producers virtually do not produce their own seed. Carrot seed production is a highly specialized process, as it is a biennial plant. Thus, the vast majority of farmers buys seed externally (Solfanelli et al. 2020).

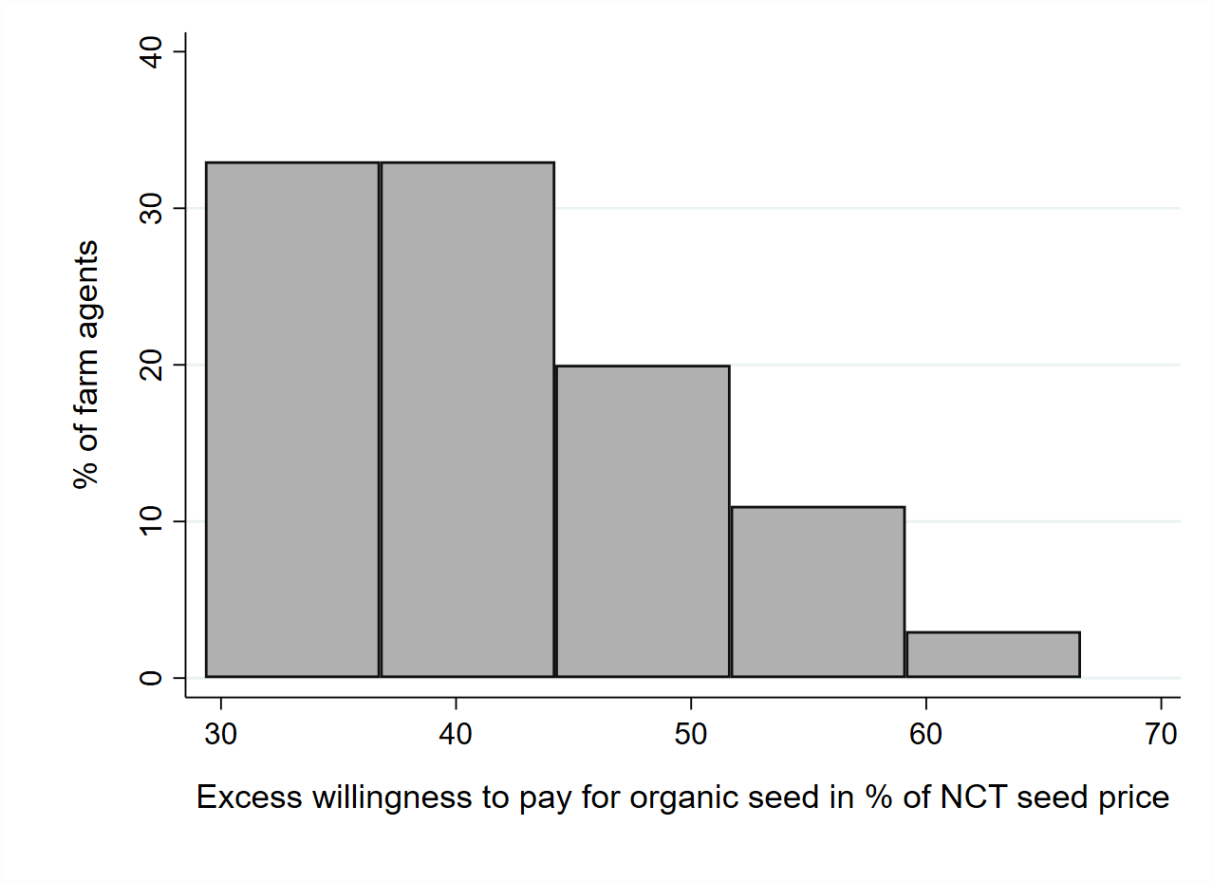

Figure A1: Estimated distribution of excess WTP in % of NCT price across the agent population (own calculations)

A.7 Triangular distributions of yields and farm gate prices at farm agent level

Table A7: Triangular distributions of yields and farm gate prices per crop and per farm type implemented in the VAL-MAS model

Farm type	Yields t/ha	Wash/storage carrot (NCT or organic seed from non-organic cultivar)	Wash/storage carrot (organic seed from organic cultivar)	Onion	Winter wheat	Winter rye	Beans	Salad	Leak	Cabbage
Vegetable	Min	24.7	19.7					13.9	16.6	39.1
Vegetable	Modus	31.5	25.2					17.9	21.3	47.4
Vegetable	Max	38.3	30.7					22.0	26.0	55.6
Arable	Min	24.7	19.7	24.1	3.4	3.0	3.2			
Arable	Modus	31.5	25.2	27.0	3.9	3.9	3.5			
Arable	Max	38.3	30.7	29.9	4.4	4.9	3.7			
	Farm gate prices €/ton									
Vegetable	Min	861.4	861.4					1,218.9	1,833.7	813.6
Vegetable	Modus	923.5	923.5					1,369.7	1,917.5	915.9
Vegetable	Max	995.6	995.6					1,504.1	2,111.0	1,028.1
Arable	Min	861.4	861.4	920.6	380.5	279.4	417.5			
Arable	Modus	923.5	923.5	994.7	422.3	334.5	451.3			
Arable	Max	995.6	995.6	1,087.6	458.1	397.8	491.5			