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Water and irrigation policy impact assessment using business simulation games: evidence from northern Germany

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Abstract

To date, studies dealing with the impact assessment of changing irrigation policies predominately rely on normative rational choice models that are subject to rather restrictive assumptions such as profit-maximizing behavior. However, there is increasing evidence that decision makers pursue multiple goals and could be affected by bounded rationality, the extent of which is likely to vary amongst farmers. Against this background, we apply a business simulations game for the ex ante policy impact assessment of irrigation water policies that has the potential to reveal the 'true' behavior of the participants. To do so, we investigate how real farmers from the northeastern part of Lower Saxony respond to a water pricing scheme and a water quota intending to reduce water withdrawals for irrigation. In the business simulation game, the participants manage a 'virtual' cash crop farm for which they have to choose the crop allocation and irrigation applications during several production periods while facing uncertain product prices and weather conditions. The results from the business simulation game reveal that the applied water quota is more effective in reducing the amount of irrigation than the water pricing scheme. Moreover, we find that the participants' risk attitude affects the applied amount of irrigation in the business simulation game.

Keywords

Business simulation games, impact assessment, water quotas, water pricing schemes, irrigation, GAMLSS, zero-adjusted regression

1 Introduction

Although water availability is declining worldwide, irrigated agriculture has considerably promoted advances in the agricultural sector and sustained the world's food demand (World Bank 2006). This comes with rising competition for water resources within and across the agricultural and domestic sector (Giordano and Villholth 2007). Similarly, growing population pressures, improved living standards, and the increasing awareness of environmental concerns have placed the need for an enhanced water resources management on the policy agenda (Johansson *et al.* 2002).

In this regard, a vast amount of literature deals with the impact assessment of changing water and irrigation policies. To do so, most studies usually rely on normative rational choice models that often assume pure profit-maximizing behavior (cf., e.g., Dono *et al.* 2010; Giannoccaro *et al.* 2010; Viaggi *et al.* 2010). Moreover, the expected utility (EU) concept and its variants form the methodological basis of a strand of research that considers the influence of decision makers' risk aversion when assessing the impact of amended water and irrigation policies (Blanco-Gutiérrez *et al.* 2011; Buchholz and Musshoff 2014; Finger 2012).

However, there is evidence that decision makers in general – and farmers in particular – neither exhibit profit-maximizing behaviour nor act completely in accordance with the expected utility concept (Bocquého *et al.* 2013; Quiggin 1982; Tversky and Kahneman 1992). Likewise, decision makers could pursue multiple goals beyond profit-maximization and risk mitigation (Benz 2009). Moreover, there might be heterogeneity amongst famers as to which extent their preferences are prone to bounded rationality (Camerer 2006; Simon 1990). As a consequence, the exclusive utilization of rational choice models could lead to false or distorted implications when assessing policy implementation effects.

In this regard, the field of behavioral economics provides alternative means that aim to circumvent the drawbacks resulting from the underlying assumptions in rational choice models. In particular, experimental approaches have been increasingly used for economic analyses in recent years (Harrison and List 2004; Levitt and List 2007; Levitt and List 2009). Within the broad spectrum of economic experiments, the utilization of business simulation games appears to be especially well-suited for the ex ante assessment of regulatory or policy implementation effects (Musshoff and Hirschauer 2014). In line with Charness *et al.* (2013), business simulation games can be classified as 'extra-laboratory experiments' since they are akin to lab experiments but also different from field experiments. In business simulations games, the randomly assigned participants deal with entrepreneurial decisions within a controlled environment framed to reflect complexities that are as realistic as required to address the particular research question (Keys and Wolfe 1990). Moreover, well-designed business simulation games provide reasonable trade-offs between 'internal' and 'external validity' (cf., e.g., Roe and Just 2009). While incentives could be provided to increase internal validity, the selection of real decision makers as participants and a realistic framing enhance external validity and, thus, inferences based on the results of the business simulation game.

Thus far, business simulation games have mainly been used for educational reasons (cf., e.g., Keys and Wolfe 1990). Yet, applications for regulatory impact assessment are rare. Notable exceptions are Musshoff and Hirschauer (2014) who analyze the effectiveness of nitrogen extensification schemes that aim to reduce nitrogen loads in agricultural production. Their results reveal that the participants' response to the applied policy measures varies substantially, although these measures are designed to have equal income effects. Using a similar approach with farmers as participants, Holst *et al.* (2014) investigate if the implementation of reward and penalty measures will foster the implementation of flowering cover crops with additional ecological benefits. Their findings show that the applied penalty scheme is more effective than the reward measure with equal income effects. Moreover, the results from their business simulation game reveal that the decisions of the farmers tend to be contingent upon their socio-demographic characteristics. Both studies confirm the above-mentioned limitations of rational choice models used for policy impact assessment. Against this background, we suggest the use of business simulation games for water and irrigation policy assessment and address the following research questions:

(1) Does the implementation of water policies affect the applied amount of irrigation water?
(2) Is either an unlimited volumetric pricing scheme or a non-binding water quota with additional charges for the excess water demand (with equal income effect) more effective?

(3) Does the risk attitude of the participants influence the applied amount of irrigation?

To do so, we confront real farmers from Germany's major irrigation area with a water quota and volumetric water pricing scheme that aim to reduce the applied amount of irrigation in a multi-period, single-person business simulation game. The novelty of our paper is threefold: first, to the best of our knowledge, this is the first study that applies business simulation games for water policy impact assessment being not confined to rational choice assumptions. Second, we conduct the experiment with real decision-makers instead of convenience groups, as commonly used in this strand of research. Third, this is the first analysis of irrigation applications based on a zero-adjusted regression model which appears to be well suited for the analysis of irrigation applications with a large probability mass at zero.

The outline of the remainder is as follows: the subsequent section reveals the generation of the behavioral hypotheses (section 2). The design of the experiment is explained in section 3, which is then followed by the sample description in section 4. Section 5 depicts a description of the applied zero-adjusted regression model, and the respective results are reported in section 6. Finally, we conclude in section 7.

2 Generation of behavioral hypotheses

In recent years, there has been a vast amount of literature that investigates the economic implications of amended water and irrigation policies for farmers, and the ways in which these might respond to additional constraints on the use of irrigation (cf., e.g., Johansson *et al.* 2002; Molle and Berkoff 2007). Within Europe, increasing environmental concerns have culminated in the enforcement of the so-called European Water Framework Directive (WFD), which aims at protecting water resources in due consideration of full cost recovery and the polluter pay principle (European Communities 2000). To do so, the WFD suggest the implementation of water pricing schemes and water quotas. Although the potential consequences have been analyzed in several case studies, Blanco-Gutiérrez *et al.* (2011) point out that the potential of water quotas and water pricing schemes for the regulation of water demand management is still uncertain. In particular, bounded rationality could be an explanation as to why farmers might respond differently to restricted irrigation capabilities, as one would expect from a pure economic perspective. Thus, we derive the following two hypotheses:

H1a: The volumetric pricing scheme with unlimited water withdrawals will reduce the applied amount of irrigation.

H1b: The non-binding water quota with additional charges for the excess water demand will reduce the applied amount of irrigation.

While water quota schemes are direct command and control instruments and the most widely applied measures to control groundwater withdrawals (Koundouri 2004), the suitability of volumetric pricing schemes is unclear. A vast amount of literature on water pricing reveals that simple volumetric water pricing schemes are not effective in terms of reducing the (irrigation) water demand. In this regard, it is often stated that the (irrigation) water demand is rather inelastic (de Fraiture and Perry 2007). In other words, only considerable price increases will induce reductions of the applied amount of irrigation. Since a substantial decline in farm income would be the consequence, the acceptability amongst farmers and the political feasibility are often seen as major obstacles when it comes to implementing these policy measures (Blanco-Gutiérrez *et al.* 2011). Therefore, we derive the following hypothesis:

H2: The non-binding water quota with additional charges will outperform the volumetric pricing scheme in terms of reducing the applied amount of irrigation, even if the income effect of the policies is the same.

Furthermore, numerous authors report that farmers are risk averse (cf., e.g., Lybbert *et al.* 2013; Menapace *et al.* 2013). In this regard, irrigation can be considered as an instrument that aims – beyond its yield-increasing effect – at reducing risks resulting from absent or lacking precipitation (Buchholz and Musshoff 2014; Finger 2013; Foudi and Erdlenbruch 2012). In addition, Groom *et al.* (2008) stress the importance of risk preferences in the evaluation of water policies. More particularly, their findings reveal that policymakers that neglect risk preferences will misinterpret input responses and welfare changes induced by amended water policies. Thus, we derive the following hypothesis:

H3: The risk attitude of the participants influences the applied amount of irrigation.

3 Design of the experiment

The experiment is divided into three parts: first, the incentive compatible, multi-period, one-person business simulation game is conducted. Subsequently, a Holt-and-Laury lottery (HLL) is carried out to elicit the risk attitude of the participants (Holt and Laury 2002) (Part 2). Finally, socio-demographic and socio-economic characteristics of the participants are collected (Part 3).

3.1 General structure of the business simulation game

In the business simulation game, the participants manage a 'virtual' cash crop farm that is highly dependent on irrigation and comprises of 200 hectares of arable land with a rather poor soil quality. The participants are real farmers and aware that their behavior will be recorded and analyzed. Hence, a non-standard subject pool is used (Harrison and List 2004). Also, the business simulation game is designed to reflect a 'realistic farming environment' with which the farmers are familiar. In this regard, the design is as simple as possible but as complex as required to answer our research questions. The participants have to manage the farm for ten production periods in each of which two major decisions have to be made:

(1) Crop acreage selection: The arable land can be allocated to sugar beets, winter wheat and winter rye, which exhibit a different tolerance to lacking precipitation or drought events.
(2) Irrigation strategy: For each crop, the participants can choose from three irrigation intensities, namely rainfed cropping without irrigation, deficit irrigation or intensive irrigation.

The choice of the crop acreage is subject to crop rotation constraints. Although these constraints are simplifications, they allow us to model the relevant relationships as appropriate as required for the analysis. The minimum amount of each crop corresponds to 10 ha (or 5 % of the arable land) in order to guarantee a crop rotation with three crops. The share of winter wheat and winter rye is constrained to 140 ha (70 %) in each case, and the amount of sugar beets is restricted to 50 ha (25 %). It is noteworthy that the entire available land (200 ha) must be allocated to the three crops, so there is no option to set aside arable land. For simplicity, the arable land is not divided into several plots and all crop levels must be integers.

In the business simulation game, we confront the participants with uncertain product prices that are chosen to reflect the prevalent price volatility in recent years. The product prices change randomly from period to period and, thus, vary between the participants. Figure 1 depicts the potential development of the product prices. Starting from an initial value that is equal for all farmers, the product prices follow an arithmetic Brownian motion (Dixit and Pindyck 1994, p. 59).

	Realized price in period 0		Uncertain price in period 1	Uncertain price in period 2
				€ 4.8/dt
		50 %	€ 4.4/dt	
Sugar beets	€ 4.00/dt			€ 4.0/dt
		50 %	€ 3.6/dt	
				€ 3.2/dt
				€ 24.0/dt
		50 %	€ 22.0/dt	
Winter wheat	€ 20.00/dt			€ 20.0/dt
		50 %	€ 18.0/dt	
				€ 16.0/dt
				€ 20.4/dt
		50 %	€ 18.7/dt	
Winter rye	€ 17.00/dt			€ 17.0/dt
		50 %	€ 15.3/dt	
				€ 13.6/dt

Figure 1. Potential product price development in the business simulation game.

While the prices for winter wheat and winter rye are perfectly correlated, the price of sugar beets is independent of the grain prices. Starting from the price in the current period, the product prices fall or rise by € 0.4/dt sugar beets, € 2.0/dt wheat and € 1.7/dt rye with a probability of 50 % in the subsequent periods.

Moreover, the crop yields are uncertain and depend on the applied amount of irrigation and the weather conditions. We distinguish between wet, normal and dry weather conditions. The participants do not know which specific weather conditions are going to ensue. However, they are aware that wet weather occurs with a probability of 20 %, normal weather with a probability of 50 % and dry weather with a probability of 30 %. Table 1 reveals the crop yields, the corresponding irrigation applications and the variable cost for the different weather conditions[1]. The variable costs comprise both the variable costs that result from the sole production of the different crops as well as the variable costs that are due to the applied irrigation.

Table 1
Crop yields, variable costs and irrigation applications for the considered weather conditions.

Weather conditions		Wet	Normal	Dry
Probability of occurrence		20 %	50 %	30 %
	---------- Sugar beets ----------			
No irrigation	Yield (dt/ha)	750	550	400
	Variable costs (€/ha)	1,500	1,500	1,500
Deficit irrigation	Yield (dt/ha)	750	750	600
	Variable costs (€/ha)	1,500	1,680	1,680
	Irrigation water (m³/ha)	0	900	900
Intensive irrigation	Yield (dt/ha)	750	750	700
	Variable costs (€/ha)	1,500	1,680	1,800
	Irrigation water (m³/ha)	0	900	1,500
	---------- Winter wheat ----------			
No irrigation	Yield (dt/ha)	90	65	45
	Variable costs (€/ha)	900	900	900
Deficit irrigation	Yield (dt/ha)	90	90	80
	Variable costs (€/ha)	900	1,080	1,080
	Irrigation water (m³/ha)	0	900	900
Intensive irrigation	Yield (dt/ha)	90	90	85
	Variable costs (€/ha)	900	1,080	1,140
	Irrigation water (m³/ha)	0	900	1,200
	---------- Winter rye ----------			
No irrigation	Yield (dt/ha)	85	75	55
	Variable costs (€/ha)	700	700	700
Deficit irrigation	Yield (dt/ha)	85	85	75
	Variable costs (€/ha)	700	820	820
	Irrigation water (m³/ha)	0	600	600
Intensive irrigation	Yield (dt/ha)	85	85	80
	Variable costs (€/ha)	700	820	880
	Irrigation water (m³/ha)	0	600	900

The variable costs without irrigation are independent of the weather conditions. However, the variable irrigation costs rise with increasing irrigation and amount to € 0.20/m³. For simplicity, we assume that no irrigation is required under wet weather conditions. Moreover, the applied amount of irrigation depends on the weather

[1] Crop yields are derived from irrigation field trials that were carried out in the region of investigation (LWK several years). To further enhance a realistic description of the 'real world' conditions all parameters in the business simulation game were validated by a panel of experienced farmers which are familiar with irrigation.

conditions and also varies between the considered crops. As it can be seen from table 1, winter rye is better adapted to lacking precipitation and requires less water than winter wheat or sugar beets.

In addition to the total gross margin (gross profit) that results from crop production, the manager of the virtual farm receives a premium of € 300 per hectare in each production period, which is assumed to cover the fixed costs of farming. The remaining net profit is assumed to cover the manager's costs of living and other expenses in each period. Therefore, there is no capital accumulation, so that each production period – reflecting one year of farming – starts with an initial capital of € 0. For simplicity, we assume that the participants have access to an interest-free loan for financing the variable factors of production. Moreover, it is not possible to store the harvested crops. Thus, all goods are sold at the end of each production period at the current market prices. The current market prices and the weather conditions of the previous period are announced at the beginning of each new production period. Moreover, the participants receive an overview about the chosen crop plan, the realized profit and the applied irrigation water after each production period. At the end of the instructions of the business simulation game, we provide control questions to test if the participants completely understand the instructions.

3.2 Changes in the policy framework

At the beginning of the business simulation game, participants are randomly assigned to one of three policy scenarios. During the first five production periods of the business simulation game, the policy framework is identical in all three policy scenarios and there is no restriction on water withdrawals for irrigation. However, in the subsequent production periods (six through ten) the policy framework conditions change whereby the policy scenarios are defined as follows:

Scenario 1 (Control scenario): The policy framework remains unchanged over the entire duration of the business simulation game.

Scenario 2 (Unlimited volumetric water pricing scheme): We provide information to the participants that water withdrawals remain unlimited but local water agencies will impose a charge of € 0.07/m^3 on the applied amount of irrigation. Thus, the variable irrigation costs increase from € 0.20/m^3 to € 0.27/m^3.

Scenario 3 (Non-binding water quota with additional charges for the excess demand): The participants are informed that irrigation can be applied without additional costs if the water withdrawals do not exceed 120,000 m^3. For the excess demand beyond 120,000 m^3, additional charges of € 0.35/m^3 apply.

Both, the water pricing scheme in scenario 2 and the water quota in scenario 3 are designed to involve the same expected loss in farm income for a perfect rational profit-maximizing decision maker. However, the induced reduction in the applied amount of irrigation differs. Under profit-maximization, irrigation applications in policy scenario 2 would remain unchanged even if water prices increase. In contrast, the implementation of the water quota in scenario 3 would reduce water withdrawals by 26.5 %. In order to compare the participants' behavior in the scenarios, we construct triplets of randomly selected participants, i.e., there are always three participants playing the business simulation game with the same price and weather developments but with different policy scenarios.

3.3 Holt and Laury lottery

The Holt and Laury (2002) lottery (HLL) is an experimental method which can be used to obtain the risk attitude of decision makers and is already established in the field of agricultural economics (Brick *et al.* 2012; Maart-Noelck and Musshoff 2014). We adapt their approach without any changes.

First, participants are introduced to the game with the explanation of the lottery. The participants are asked to choose between two different lotteries: A (i.e., the safer alternative) and B (i.e., the riskier alternative) whereby the outcomes are always positive. In lottery A, the participants can either win € 2.00 or € 1.60, whereas the riskier lottery B offers winnings of € 3.85 or € 0.10. The probabilities of achieving the two possible prizes in the lotteries are systematically varied at 10 % intervals beginning at € 2.00 in lottery A (€ 3.85 in lottery B) with a possibility of 10 %, or € 1.60 (€ 0.10 in lottery B) with a probability of 90 %. Consequently, there exist ten different decision situations whereby the expected value increases in both lotteries. In decision situation five, the expected value of lottery B becomes higher than the expected value of lottery A. The risk attitude is indicated by the HLL-value, varying from one through nine. The HLL-value depicts the number of 'safe choices' when the decision from lottery A changes to the more risky lottery B. Farmers who choose lottery A four times are risk neutral. When farmers choose the safer lottery A zero to three times, it indicates risk seeking whereby a HLL-value between five and 10 shows risk aversion. HLL-values of zero or ten are consolidated to one or nine, respectively.

3.4 Incentives for well-conceived decisions

It is common practice to set incentives in economic experiments since former studies reveal that incentives influence the behavior of participants and help to improve decision making (Cooper et al., 1999; Friedman, 1998; Harrison, 1994). Although incentives can also cause biases, Camerer and Hogarth (1999), summarize in a comprehensive review that incentives generally result in better experimental findings.

In order to motivate the participants, each participant receives a representation allowance of € 10 if the experiment is completed. This corresponds to an average hourly wage of € 20 as the average time for passing the business simulation game in the conducted pretest amounts to 30 minutes. In addition to the representation allowance, we provide additional cash prizes of up to € 1,000 in total to ensure incentive compatibility. To do so, four of the expected 90 participants are randomly drawn as winners. Each winner can receive a maximum cash price of € 250 where the payout depends on the winners' financial success in the business simulation game. The actually paid cash prize depends on the second lowest gain (net profit) of all production periods in the business simulation game. The participant amongst the four selected winners who realizes the highest second lowest gain receives € 250. The remaining winners receive a share of € 250 corresponding to the height of their second lowest gain[2].

Furthermore, the HLL, which is carried out for each participant, is incentive compatible. Each participant has the chance to win between € 0.10 and € 3.85 depending on his or her risk attitude.

[2] We do not rank the participants according to their business success and do not reward the first ranked farmer as is often done in stock exchange simulation games (Bothos *et al.* 2012). Rewarding the highest gain could lead to risk-seeking behavior. In contrast, rewarding the second lowest gain is expected to foster risk management strategies that impede low gains. We select the second lowest gain to avoid a loss of motivation that might result from a low gain in the very first periods of the business simulation game.

4 Characterization of the participants

The computer-based experiment was carried out in the second half of the year 2014. The experiment was addressed to farmers from the northeastern part of Lower Saxony which is known as Germany's major irrigation area. Historically, in this region located south to Hamburg, farmers have mainly used groundwater resources for irrigation and are therefore able to grow a multitude of water-demanding crops such as sugar beets or winter wheat. Thus, despite poor soil quality, a highly specialized cash crop farming system could be established. Currently a water quota restricts water withdrawals. In total, 90 farmers completed the experiment successfully with 30 farmers playing in each policy scenario. The experiment was conducted during farm visits for which the participants were selected from mailing lists of a local machinery cooperative and extension service agencies. In addition, 39 farmers preferred to participate online and are evenly distributed between the policy scenarios. The socio-demographic and socio-economic characteristics of the participants in the three policy scenarios are summarized in Table 2.

Table 2
Selected socio-demographic and socio-economic characteristics of the participants (N=90).

Characteristics	Mean	SD [a]	Min.	Max.
Age in years	39.9	12.1	20.0	66.0
Share of male participants (%)	97.7 %	-	-	-
Years of education	13.0	2.9	9.0	18.0
Share with agricultural training (%)	91.1 %	-	-	-
Share with agricultural university degree (%)	31.1 %	-	-	-
HLL-value [b]	5.2	1.7	2.0	9.0
Hectares of arable land	180.7	131.7	12.0	560.0
Share of mainstay farms (%)	97.7 %			
Share of irrigated arable land (%)	89.7	14.8	30.0	100.0
Commonly applied irrigation (m^3/ha)	640.2	207.7	100.0	1,150.0
Granted water quota (m^3/ha)	748.9	103.2	160.0	1,000.0

[a] Standard deviation
[b] 1-3 = risk seeking, 4 = risk neutral, 5-9 = risk averse

On average, the participants are 39.9 years old, where the youngest participant is 20 years and the oldest is 66 years. According to the HLL, the participants are on average slightly risk averse. The vast majority of the participants is male and manages a mainstay farm. On average, the participants had 13.0 years of education, where the share of farmers with an agricultural training is 91.1 % and the share with an agricultural university degree is 31.1 %. On average, the participants manage 180.7 ha of arable land of which 89.7 % are irrigated. The participants withdraw 640.2 m³/ha water for irrigation and the granted water quota amounts to 748.9 m³/ha on average.

5 Zero-adjusted regression models for analyzing the applied amount of irrigation

In terms of design, the business simulation game produces a longitudinal data set due to the recurring decisions made by the farmers, which may vary in the course of the 10 periods of the game. Moreover, the survey provides time-invariant[3] socio-demographic and socio-economic characteristics of the participants. Suitable models for this specific kind of data would be random effects models with demeaned context variables which are also referred to as 'hybrid models' (Allison 2009) or generalized linear mixed models (GLMMs) that are able to account for both fixed and random effects (Lee and Nelder 2001). Yet, these models are rather restrictive with regard to the (conditional) distribution of the dependent variable which is confined to the normal distribution in random effects models or has to belong to the exponential family in the case of GLMMs. However, the applied amount of irrigation y – which is the dependent variable in our analysis – exhibits a rather large amount of zeros referring to situations in which no irrigation is applied (figure 2).

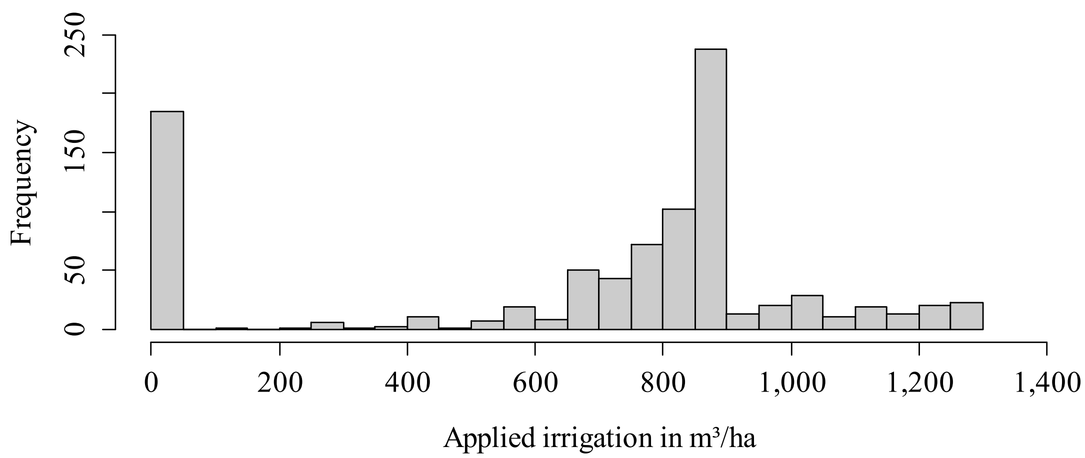

Figure 2. Histogram of the participants' applied amount of irrigation in the business simulation game.

[3] During the time the survey was conducted.

Accordingly, the assumption of normality does not hold for the dependent variable 'applied amount of irrigation'. Thus, both the hybrid model and the class of GLMMs are not necessarily the best modeling environment with regard to our data set. A rather novel approach to deal with excess zeros of a continuous dependent variable is the utilization of so-called zero-adjusted regression models. Thus far, these models have mainly been used for modelling data of insurance claims (cf., e.g., Klein *et al.* 2014; Tong *et al.* 2013) which usually comprise a large probability mass at zero[4]. For additional applications, Heller *et al.* (2006) suggest the analysis of precipitation which is either zero in the case of a dry day or, otherwise, exhibits a continuous non-negative value. A similar pattern is observed in the case of irrigation.

Generally, the zero-adjusted regression model is characterized by a mixed discrete-continuous probability function of the applied amount of irrigation y which can be formalized as:

$$f(y) = \begin{cases} \pi, \ y = 0 \\ 1 - \pi \, g(y), \ y > 0 \end{cases} \quad (1)$$

The probability of no irrigation is given by π, while $g(y)$ denotes the density of the continuous part of the model for which any continuous distribution could be chosen given that the first and second derivative of the log-likelihood can be computed (Klein *et al.* 2014). In this regard, the literature on insurance claims modeling suggest the use of the gamma or inverse Gaussian distribution (cf., e.g., Klein *et al.* 2014; Tong *et al.* 2013).

The zero-adjusted regression model is based on the generalized additive models for location, scale and shape environment (GAMLSS). The implementation is done by means of the respective GAMLSS package in R. GAMLSS is a very general class of (semiparametric) regression models that have been proposed by Rigby and Stasinopoulos (2005). GAMLSS features a large variety of response distributions for the dependent variable. Thus, the exponential family assumption such as in GLMMs is relaxed. Moreover, not only the mean (location) but also all other (scale and shape) parameters of the distribution can be modeled explicitly in terms of both fixed and random effects. A further advantage of GAMLSS is the fact that we can formalize one

[4] Jørgensen and Paes De Souza (1994) use a similar approach for insurance claim analysis. The applied Tweedie model, however, has the drawback that the zero probability does not depend on covariates.

coherent model for the distribution of the dependent variable (including the probability mass at zero) (Kneib 2013).

Our model can be formalized as follows. Let y_{in} denote the applied amount of irrigation in period n of the participant i for $i = 1,2, \ldots, I$ and $n = 1,2, \ldots, N$. If the continuous part of the dependent variable is, for instance, described by a gamma distribution[5], the respective zero-adjusted gamma model (ZAGA) comprises three monotonic link functions that relate the mean μ and dispersion (standard deviation) σ of the dependent variable and the probability of no irrigation π to the covariates:

$$\log(\mu) = \eta_1 = X_1\beta_1 + \sum_{j=1}^{J_1} Z_{j1}\gamma_{j1} \tag{2}$$

$$\log(\sigma) = \eta_2 = X_2\beta_2 + \sum_{j=1}^{J_2} Z_{j2}\gamma_{j2} \tag{3}$$

$$\text{logit}(\pi) = \eta_3 = X_3\beta_3 + \sum_{j=1}^{J_3} Z_{j3}\gamma_{j3} \tag{4}$$

X_k denotes a known design matrix and β_k is the corresponding regression coefficient vector for the three distribution parameter k = 1, 2, 3. In general, the term $Z_{jk}\gamma_{jk}$ comprises non-parametric functions such as smoothing splines and/or random effects[6]. It should be noted that X_k, $Z_{jk}$and γ_{jk} may be different, the same or share only some of the set of covariates. In our analysis, Z_{jk} shrinks to a design matrix of dummy variables Z_k and γ_{jk} becomes the random intercept γ_{ki} of participant i which could be considered for all distribution parameter k if required. This approach allows us to explicitly determine the factors that could explain (a) the mean and (b) the dispersion of the applied amount of irrigation (if there is irrigation) as well as the (c) probability of situations in which no irrigation is applied. The ZAGA model is estimated by maximization of the penalized likelihood. Variable selection for the final model is done by the generalized Akaike information criterion (GAIC). This selection criterion is more

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5 According to the GAIC, previous analyses revealed that the ZAGA model is superior to a model with zero-adjusted inverse Gaussian distribution.

6 Might require the prior estimation of hyperparameters for which several methods are available (Rigby and Stasinopoulos 2005; Stasinopoulos and Rigby 2007). Technically, we use an interface function of the additional GAMLSS.add package that allows us to apply the automatic smoothness selection capabilities provided in the MGCV package in R (Wood 2006).

robust to highly skewed data and kurtosis in the data than the Akaike information criterion AIC (Bozdogan 2000).

6 Behavioral impact of irrigation policy measures

Table 3 portrays the amount of irrigation that the participants applied in the business simulation game.

Table 3
Mean and standard deviation of the applied irrigation in m³/ha according to assigned irrigation policies.

Policy scenario	Irrigation in periods 1-5		Irrigation in periods 6-10	
	Mean	SD [a]	Mean	SD
Control scenario (1)	670.6	382.3	694.8	398.4
Water pricing scheme (2)	680.0	378.7	679.6	385.7
Water quota (3)	719.6	387.1	618.2	344.5
Mean	690.1	382.7	-	-

[a] Standard deviation

We distinguish between the periods 1-5 with no restrictions on the water withdrawals and the periods 6-10 in which the different policy measures are applied. Comparing the amount of irrigation that is applied in periods 1-5 and periods 6-10 allows us to draw a first conclusion regarding the effectiveness of the applied irrigation policy scenarios. While we observe a slight increase in the applied amount of irrigation in the control scenario (1), irrigation declines in policy scenarios 2 and 3 in which the water pricing scheme and the water quota are applied (table 3). However, the irrigation applications in the period 6-10 in the control scenario (1) (p-value = 0.560) and the scenario with water pricing scheme (2) (p-value = 0.896) do not differ significantly from the amount of irrigation in the first five periods according to the Wilcoxon signed-rank test. On the contrary, we find a significant impact of the water quota in scenario 3 (p-value = 0.01) with a decline in the mean of the applied amount of irrigation from 719.6 to 618.2 m³/ha.

To further investigate the results from the business simulation game, we apply the ZAGA model[7]. Generally, variables that stem from the business simulation game such as the realized product prices and socio-demographic or socio-economic characteristics from the survey are considered as possible covariates. Moreover, dummy variables that

[7] Results for a model with Gaussian distribution are reported in appendix A.

correspond to the assigned policy scenarios are considered. In this regard, the applied amount of irrigation in the periods 1-5 is the reference situation (as the policy measures are enforced by the beginning of the 6th period) for all three scenarios. Consequently, the dummy variables signal the implementation effects of the applied water policy scenarios in the analysis. To account for the variation in the irrigation applications resulting from the weather conditions, we also provide dummies for normal and dry weather conditions with wet weather being the reference. For the final model, we manually choose the three policy scenario dummies as well as the HLL-value from the HLL for all model parameters since these variables are essential to answer our research questions. In addition, the GAIC routine[8] identifies 11 different variables from the remaining set of possible covariates of which some are related to more than one of the three distribution parameter.

Table 4 reveals the results for the three parameters μ, σ and π of the final ZAGA model[9]. Estimates for π are reported as log odds. Here, the odds can be defined as the ratio between the probability of the occurrence of no irrigation over the probability of irrigation. A one-unit increase in the estimates for π refers to the expected change in the log odds, assuming that all other covariates are held constant. In addition, table 4 reports the corresponding odds ratios that are computed by exponentiating the log odds. By definition, odds ratios reflect the percentage change in the odds of the occurrence of no irrigation due to an increase by one unit in the respective covariate, assuming that all other covariates are held constant. Hence, increases in odds correspond to increasing probabilities of the occurrence of no irrigation. In addition, estimates for μ and σ are presented as (exponentiated) logs.

Based on the results of the ZAGA model in table 4, our findings with regard to our hypotheses are as follows:

Hypothesis 1a, which states that the volumetric pricing scheme with unlimited water withdrawals, as applied in policy scenario 2, will reduce the applied amount of irrigation, is confirmed. In this regard, the results in table 4 reveal that the applied amount of irrigation slightly declines by 2.9 % (1/0.97-1) on average in cases when

[8] The GAIC routine selected random intercepts for the parameter μ and σ. However, we needed to exclude the random intercept term for σ as the model did not successfully converge.

[9] Model validation results are shown in appendix B.

there is irrigation. This finding is rather surprising as water withdrawals would have remained unchanged for a perfect rational profit-maximizing decision maker.

Table 4
Results of the ZAGA model for investigating the applied amount of irrigation y in the business simulation game.

	Estimate	Exp (estimate)	Standard Error	t-statistic	p-value
$\log(\mu)$: Mean of the applied amount of irrigation (m³/ha) if y>0					
Intercept	6.220	502.762	0.042	146.843	0.000
Dummy control scenario (1)	0.018	1.018	0.009	2.044	0.041
Dummy water pricing scheme (2)	-0.028	0.972	0.013	-2.086	0.037
Dummy water quota (3)	-0.142	0.867	0.015	-9.495	0.000
HLL-value	0.014	1.014	0.002	8.008	0.000
Dummy dry weather	0.214	1.239	0.009	24.429	0.000
Product price sugar beets	-0.027	0.973	0.010	-2.750	0.006
Dummy mainstay farming	0.509	1.663	0.022	23.163	0.000
$\log(\sigma)$: Dispersion of the applied amount of irrigation (m³/ha) if y>0					
Intercept	0.760	2.137	0.547	1.389	0.165
Dummy control scenario (1)	-0.122	0.885	0.079	-1.544	0.123
Dummy water pricing scheme (2)	0.583	1.791	0.079	7.377	0.000
Dummy water quota (3)	0.604	1.830	0.079	7.653	0.000
HLL-value	-0.082	0.921	0.015	-5.564	0.000
Dummy dry weather	0.359	1.432	0.056	6.384	0.000
Product price wheat	-0.119	0.887	0.020	-6.105	0.000
Product price sugar beets	0.555	1.743	0.085	6.529	0.000
Years of education	-0.062	0.940	0.010	-6.079	0.000
Dummy agricultural training	0.181	1.198	0.104	1.733	0.084
Dummy mainstay farming	0.279	1.321	0.187	1.488	0.137
Dummy cash crop farming	-0.358	0.699	0.081	-4.415	0.000
Share of irrigated land (%)	-0.006	0.994	0.002	-2.873	0.004
Granted water quota (m³/ha)	-0.001	0.999	0.000	-5.147	0.000
Affected by water restrictions (%)	-0.005	0.995	0.001	-4.696	0.000
$\text{logit}(\pi)$: Probability of no irrigation					
Intercept	0.783	2.189	1.280	0.612	0.541
Dummy control scenario (1)	0.062	1.064	0.284	0.219	0.827
Dummy water pricing scheme (2)	0.058	1.059	0.284	0.203	0.839
Dummy water quota (3)	0.008	1.008	0.285	0.029	0.977
HLL-value	0.022	1.022	0.051	0.426	0.671
Dummy normal weather	-3.857	0.021	0.463	-8.338	0.000
Product price wheat	-0.378	0.685	0.079	-4.763	0.000
Product price sugar beets	1.492	4.447	0.311	4.805	0.000
No. of observations	900				
Global deviance	9,193				
GAIC	9,419				

A possible explanation could be that the behavior of the participants is affected by the normative commitment to reduce irrigation (Tyler 2006). Moreover, it appears that the enforcement of the water pricing scheme in policy scenario 2 involves an increase of the dispersion parameter σ by the factor 1.79 or 79 %.

Hypothesis 1b, stating that the non-binding water quota with additional charges for the excess water demand (policy scenario 3) will reduce the applied amount of irrigation, is confirmed. In this regard, the results of the ZAGA model reveal that the applied amount of irrigation in policy scenario 3 is, on average, 13.3 % (1/0.87-1) lower as compared to the reference periods 1-5. Similar to the policy scenario 2, we observe a rise in the dispersion of the applied amount of irrigation by 79 % in policy scenario 3.

In light of hypotheses 1a and 1b, we confirm ***Hypothesis 2*** which states that the non-binding water quota (policy scenario 3) will outperform the volumetric pricing scheme (policy scenario 2) in terms of the reduction of the applied irrigation even if the expected income effect is the same. However, it appears that the increase in the dispersion parameter σ in policy scenario 2 is rather large relative to the moderate effect on the mean.

Hypothesis 3, which supposes that the risk attitude of the participants influences the applied amount of irrigation, is confirmed. From table 4, we see that the risk attitude, as measured by the HLL-value, has a positive effect on the mean and a negative effect on the dispersion of the applied amount of irrigation. This finding indicates that risk-averse farmers do not only apply more irrigation water but also alter their irrigation strategy less frequently.

In addition, the GAIC routine identified further socio-economic characteristics of the participants and variables from the business simulation game as covariates. It appears that the product price of sugar beets has a slight negative effect on the mean of the applied amount of irrigation. In contrast, it seems that participants for whom agriculture is the major source of income (mainstay farming) apply more irrigation on average. With regard to the dispersion of the applied amount of irrigation σ, we find positive effects for the product price of sugar beets and the mainstay farming dummy. On the contrary, the dispersion parameter σ appears to be lower for increases in the product price of wheat and amongst cash crop farms. We also observe a negative effect on σ from the water quota that is granted to the participants by the local water supply agencies, the commonly applied amount of irrigation, the share of irrigated arable land

and the degree to which the participants state that they would be negatively affected by restrictions on water withdrawals for irrigation. Furthermore, it appears that the probability of situations without irrigation π is not subject to the policy scenarios to which the participants are assigned[10]. In other words, none of the applied policy measures is likely to make farmers quit irrigation. We would have expected this result. Nevertheless, the explicit consideration of covariates for π could provide interesting insights under different conditions where irrigation is less profitable or when restrictions on irrigation are more severe.

7 Conclusions

Rising competition for water resources and increasing environmental concerns have placed the need for an enhanced water resources management on the policy agenda. In this respect, a vast amount of literature deals with the impact assessment of changing water and irrigation policies. Commonly, most studies rely on normative rational choice models that are subject to rather restrictive assumptions such as profit-maximizing behavior. However, there is increasing evidence that decision makers pursue multiple goals and are affected by bounded rationality. This paper addresses these limitations and suggests the use of economic experiments in general, and business simulations games in particular, for the ex ante policy impact assessment of irrigation water policies. This experimental approach is not confined to the underlying assumptions in rational choice models and has the potential to reveal the 'true' behavior of the participants.

In doing so, this paper investigates how real farmers from Germany's major irrigation area respond to a volumetric water pricing scheme and a water quota intending to reduce water withdrawals for irrigation in a tailor-made business simulation game. In the business simulation game, the participants manage a 'virtual' cash crop farm for which they have to choose the crop allocation and irrigation applications during several production periods, while facing uncertain price and weather conditions. The water quota and the water pricing scheme are applied in the course of the game and are designed to involve the same expected loss in farm income. We investigate the impact

[10] We cannot rule out that the estimates in the logit link are biased since we had to exclude the dummy for dry weather conditions from the variable selection process to avoid convergence difficulties related to complete and quasi-complete separation of the dependent variable in the logit link (cf., e.g., Albert et al. 1984). However, we can assure that the estimates for μ and σ are unbiased as both the model with and without the dummy for dry weather conditions provide exactly the same results for the mean and dispersion parameter. Thus, our major findings are not affected.

of both irrigation water policy measures by means of a zero-adjusted regression approach which is based on the GAMLSS framework and appears to be well suited for analyzing irrigation applications.

Our results from the business simulation game reveal that, despite equal income effects, the applied water quota is more effective in reducing the amount of irrigation water than the volumetric water pricing scheme. However, we find that the water pricing scheme involves a moderate decline in the irrigation applications on average which, however, would not be in line with the result of a 'hypothetical' perfect rational profit-maximizing decision maker. Moreover, the implementation of both policy measures tends to increase the variation in the water withdrawals. This might indicate that the participants respond differently to the implementation of the volumetric water pricing scheme. In addition, we find that the participants' risk attitude has an impact on the amount of irrigation used in the business simulation game. In this regard, our results indicate that farmers do not only apply more irrigation with increasing risk aversion but also alter their irrigation strategy less frequently. This finding stresses the importance of risk preferences in the assessment of irrigation water polices (Groom *et al.* 2008).

The generalization of our results deserves some further attention. By design, the external validity of experimental approaches, as applied in this study, is limited to a certain extent (Roe and Just 2009). Our endeavour to mitigate this drawback is twofold: first, the participants are exclusively confined to famers who are potentially affected by changing irrigation and water policies. This makes our study different from many other experimental approaches that often rely on convenient groups. Thus, we avoid a potential bias due to different preferences between, e.g., students and farmers (Maart-Noelck and Musshoff 2014). Second, the business simulation game differs from artificial laboratory experiments due to a realistic framing of the decision situation with which the farmers are familiar. Nevertheless, we admit that economic reality is more complex than the setting of the business simulation game. For instance, farmers are usually not completely aware of the exact relationship between crop yields and the applied amount of irrigation. Moreover, despite all efforts to assure incentive compatibility, the incentive situation under real-world condition is likely to be different.

Notwithstanding these limitations, we believe that business simulation games are a helpful tool for ex ante policy impact assessment that can potentially contribute to a more efficient design of irrigation water policies. One of the strengths of the experimental approach lies in its flexibility regarding the design and framing of the decision situation with which the participants have to deal. The business simulation game could be easily adapted to fit the specific needs required under different conditions or in other regions. For instance, one could disaggregate the single production periods to reflect the water demand of the considered crops as well as at the aggregated farm level in a more realistic manner. In addition, the considered water quota could be extended to allow for overconsumption in the single production periods which has to level out over a certain amount of years. In this regard, it might be an interesting field of research to investigate the effect of the additional temporal flexibility on the overall water withdrawals for irrigation in an economic experiment.

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Appendix A. Gaussian regression model results

The results in table A.1 refer to a model which is similar to linear mixed model as it relies on a Gaussian distribution. What makes this model different is the fact that the dispersion parameter σ is directly related to covariates. Variables are selected by means of the GAIC selection criterion. It is to note that the GAIC routine selected a random intercepts term for the dispersion parameter σ. Comparing the GAIC scores from table 4 (in the manuscript) and table A.1 reveals that the ZAGA model clearly outperforms the Gaussian model.

Table A.1
Results for the Gaussian model.

	Estimate	Exp (estimate)	Standard Error	t-statistic	p-value
μ: Mean of the applied amount of irrigation (m³/ha) (identity link)					
Intercept	1.615	-	31.854	0.051	0.960
Dummy control scenario (1)	-7.829	-	5.486	-1.427	0.154
Dummy water pricing scheme (2)	-11.116	-	6.817	-1.631	0.103
Dummy water quota (3)	-46.340	-	7.858	-5.897	0.000
HLL-value	4.052	-	1.136	3.567	0.000
Dummy normal weather	811.702	-	4.842	167.637	0.000
Dummy dry weather	1035.833	-	9.493	109.116	0.000
Product price sugar beets	-20.207	-	6.375	-3.170	0.002
Dummy mainstay farming	25.859	-	14.934	1.732	0.084
Hectares of arable land	-0.030	-	0.016	-1.903	0.057
Commonly applied irrigation (m³/ha)	0.070	-	0.012	5.987	0.000
$\log(\sigma)$: Dispersion of the applied amount of irrigation (m³/ha)					
Intercept	5.331	1.033	0.374	14.247	0.000
Dummy control scenario (1)	0.033	1.033	0.067	0.483	0.629
Dummy water pricing scheme (2)	0.337	1.400	0.067	4.990	0.000
Dummy water quota (3)	0.573	1.774	0.068	8.472	0.000
HLL-value	-0.080	0.923	0.013	-6.364	0.000
Dummy dry weather	0.993	2.700	0.052	19.156	0.000
Product price wheat	0.049	1.050	0.016	2.963	0.003
Product price sugar beets	-0.237	0.789	0.069	-3.442	0.001
Share of irrigated land (%)	-0.010	0.990	0.002	-6.055	0.000
No. of observations	900				
Global deviance	10,700				
GAIC	10,886				

Appendix B. Validation of the fitted (zero-adjusted) regression models

Figure B.1 reveals residual plots of the ZAGA model and figure B.2 shows the residual plots for the fitted Gaussian model. Each figure comprises a plot of residuals against fitted values, a density plot and a normal Q-Q plot of the residuals.

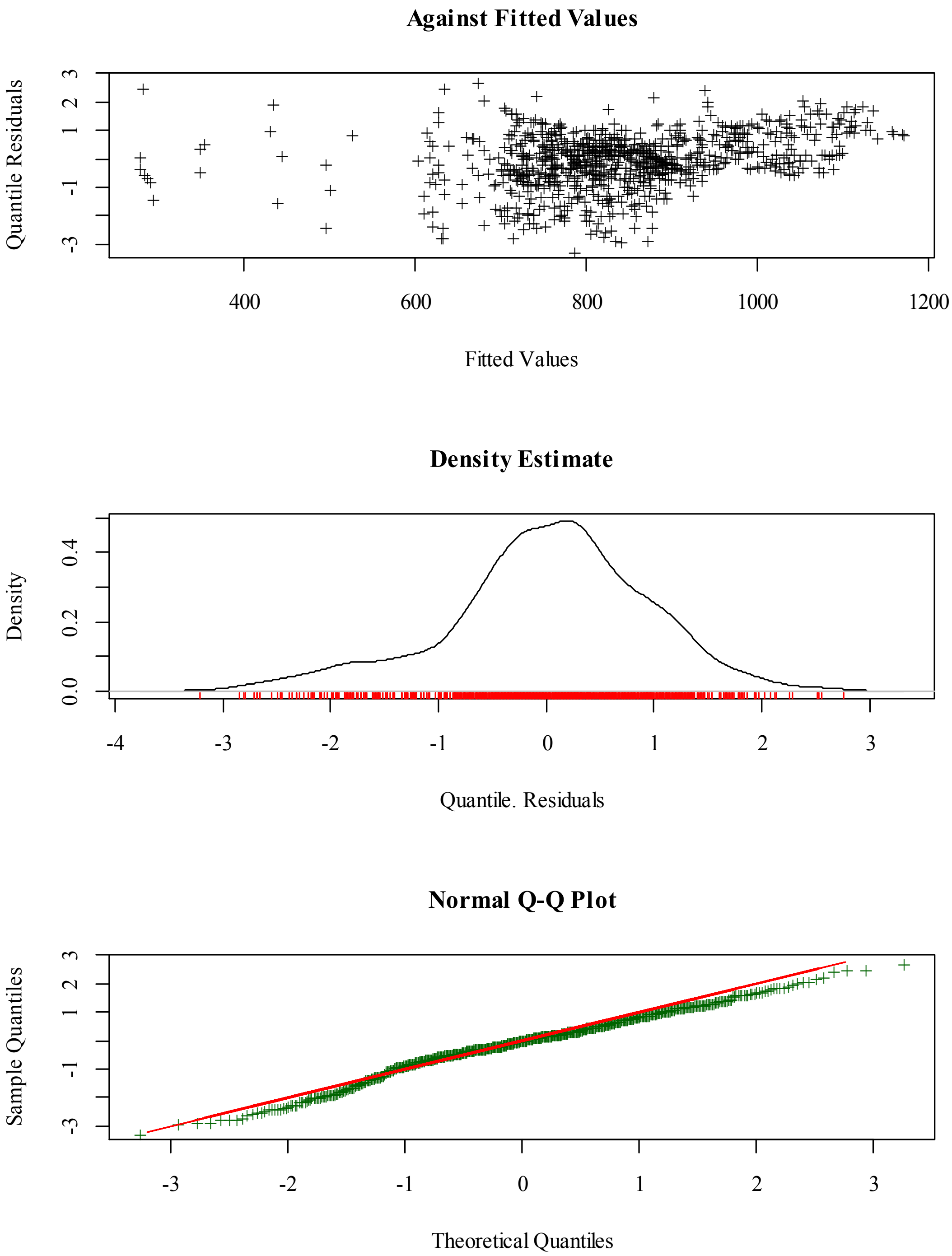

Figure B.1. Residual plots from the fitted ZAGA model.

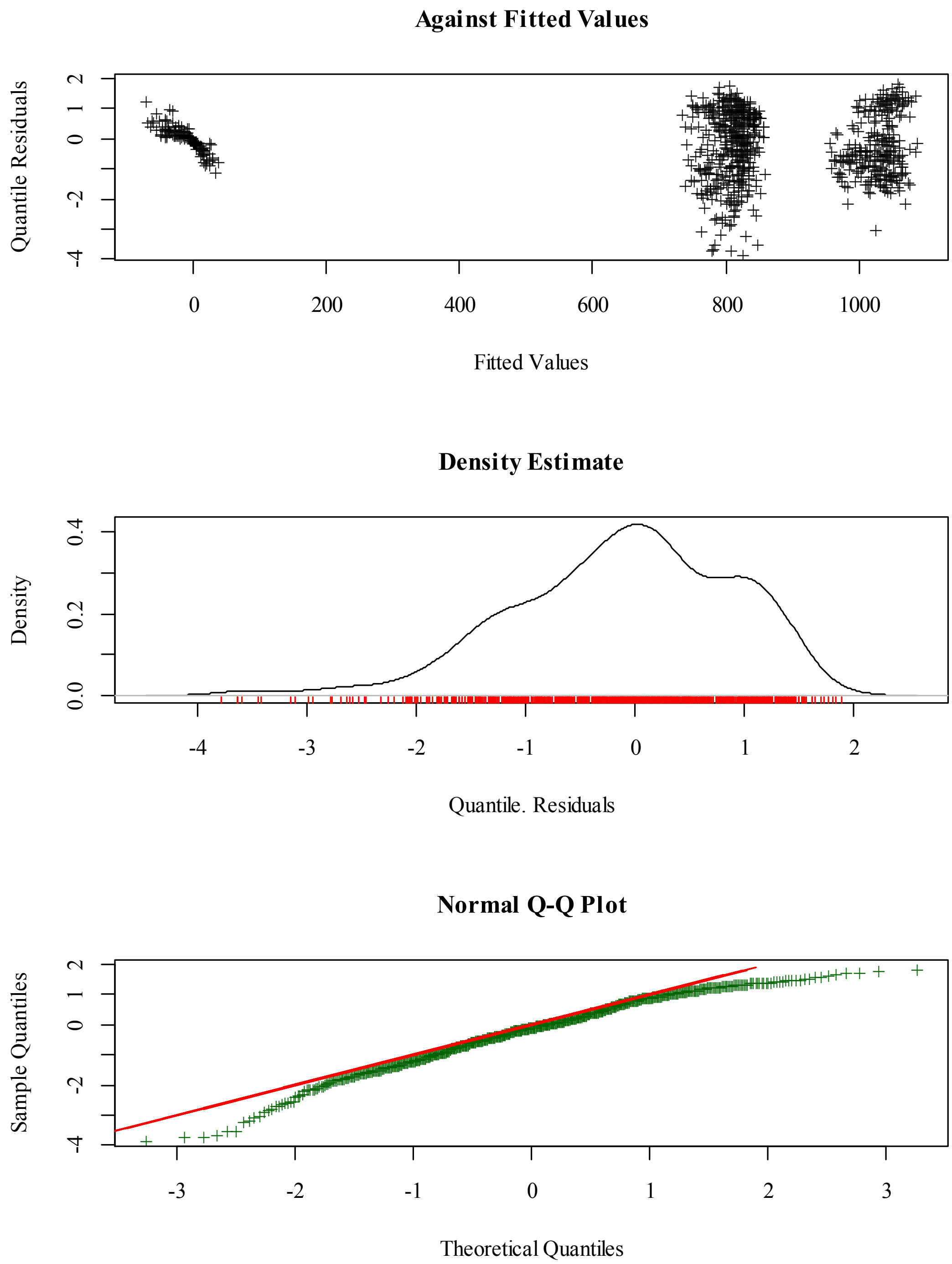

Figure B.2. Residual plots from the fitted Gaussian model.

Diskussionspapiere

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2000		
0001	Brandes, W.	Über Selbstorganisation in Planspielen: ein Erfahrungsbericht, 2000
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2001		
0101	Leserer, M.	Zur Stochastik sequentieller Entscheidungen, 2001
0102	Molua, E.	The Economic Impacts of Global Climate Change on African Agriculture, 2001
0103	Birner, R. et al.	‚Ich kaufe, also will ich?': eine interdisziplinäre Analyse der Entscheidung für oder gegen den Kauf besonders tier- u. umweltfreundlich erzeugter Lebensmittel, 2001
0104	Wilkens, I.	Wertschöpfung von Großschutzgebieten: Befragung von Besuchern des Nationalparks Unteres Odertal als Baustein einer Kosten-Nutzen-Analyse, 2001
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0201	Grethe, H.	Optionen für die Verlagerung von Haushaltsmitteln aus der ersten in die zweite Säule der EU-Agrarpolitik, 2002
0202	Spiller, A. u. M. Schramm	Farm Audit als Element des Midterm-Review : zugleich ein Beitrag zur Ökonomie von Qualitätsicherungssytemen, 2002
2003		
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0405	Spiller, A. u. T. Staack	Brand Orientation in der deutschen Ernährungswirtschaft: Ergebnisse einer explorativen Online-Befragung, 2004
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0407	Inderhees, P. et al.	Determinanten der Kundenzufriedenheit im Fleischerfachhandel
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Die Wurzeln der Fakultät für Agrarwissenschaften reichen in das 19. Jahrhundert zurück. Mit Ausgang des Wintersemesters 1951/52 wurde sie als siebente Fakultät an der Georgia-Augusta-Universität durch Ausgliederung bereits existierender landwirtschaftlicher Disziplinen aus der Mathematisch-Naturwissenschaftlichen Fakultät etabliert.

1969/70 wurde durch Zusammenschluss mehrerer bis dahin selbständiger Institute das **Institut für Agrarökonomie** gegründet. Im Jahr 2006 wurden das Institut für Agrarökonomie und das Institut für Rurale Entwicklung zum heutigen **Department für Agrarökonomie und Rurale Entwicklung** zusammengeführt.

Das Department für Agrarökonomie und Rurale Entwicklung besteht aus insgesamt neun Lehrstühlen zu den folgenden Themenschwerpunkten:

- Agrarpolitik
- Betriebswirtschaftslehre des Agribusiness
- Internationale Agrarökonomie
- Landwirtschaftliche Betriebslehre
- Landwirtschaftliche Marktlehre
- Marketing für Lebensmittel und Agrarprodukte
- Soziologie Ländlicher Räume
- Umwelt- und Ressourcenökonomik
- Welternährung und rurale Entwicklung

In der Lehre ist das Department für Agrarökonomie und Rurale Entwicklung führend für die Studienrichtung Wirtschafts- und Sozialwissenschaften des Landbaus sowie maßgeblich eingebunden in die Studienrichtungen Agribusiness und Ressourcenmanagement. Das Forschungsspektrum des Departments ist breit gefächert. Schwerpunkte liegen sowohl in der Grundlagenforschung als auch in angewandten Forschungsbereichen. Das Department bildet heute eine schlagkräftige Einheit mit international beachteten Forschungsleistungen.

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