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Social Valuation of Genebank Activities: Assessing Public Demand for Genetic Resource Conservation in the Czech Republic

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Abstract: The use of diverse genetic resources to breed improved crop varieties has been a key driver of agricultural productivity improvements in the past century. At the same time, the adoption of modern varieties has contributed to substantial loss of traditional varieties. In this analysis, we estimate the social value provided by several proposed crop diversity conservation programs to be carried out by the Czech genebank system. We use a double-bounded dichotomous choice model to estimate the willingness-to-pay (WTP) for conserving additional crop varieties in the genebank for ten years using data collected through an online contingent valuation survey administered to a sample representative of the general Czech population (1037 respondents) and a smaller sub-sample representative of the agricultural region of South Moravia (500 respondents). Mean WTP was found to be about $9 for both the Czech and S. Moravian sub-samples, corresponding to country-wide benefits of ~$68 million. These benefits increase by 6–7% for every ten varieties conserved, implying total welfare benefits of ~$84 million for a program conserving the maximum number of 35 additional crop varieties offered in the experiment. The study illustrates an empirical approach of potential value for policymakers responsible for determining funding levels for genetic resource conservation.

Keywords: crop diversity; plant genetic resources for food and agriculture (PGRFA); public goods; contingent valuation; double-bounded dichotomous choice; willingness to pay

1. Introduction

Plant genetic resources for food and agriculture (PGRFA) comprise both the diversity of crop varieties, as well as the wild relatives of crops. A primary value of these resources is the use of PGRFA to breed new crop varieties that are more productive and resilient. For example, the use of rice and wheat varieties from diverse backgrounds to breed high-yielding, semi-dwarf cultivars and the dissemination of these varieties in the developing world helped to launch the Green Revolution, along with the increased use of fertilizers and pesticides [1], and led to substantial increases in crop yield and production, a reduction in child malnourishment, and reduced crop prices in developing countries [2]. The use of genetic resources in plant breeding has been shown to have a high rate of return on investment, with Marasas et al. (2004) finding that efforts to breed wheat cultivars resistant to leaf rust had an internal rate of return of 41% [3], and Brennan and Malabayasas (2011) reporting that an investment in rice improvement efforts of about US$4.8 billion (2009 values) produced just over US$100 billion in benefits [4]. Thus, the availability of diverse plant genetic resources has been shown to be essential for breakthroughs in plant breeding that in turn have led to substantial increases in agricultural productivity.

However, in spite of the looming challenges of climate change and a rapidly growing world population, recent years have seen a slowdown in the growth of the yields of rice, wheat, maize and soybeans, as well as spending on agricultural research and development in the U.S. [5], with funding for international agricultural research slowing after 1990 as well [6]. At the same time, the development of improved crop varieties, along with pressures such as land clearing, development, urbanization and the spread of pests and diseases, has led to the loss of traditional, less profitable crop varieties [7].

Such genetic erosion has led to the increased homogenization of agricultural production, and has undermined the resilience of the overall agricultural system by limiting the genetic resources available for breeding more productive and resistant crop varieties in the future. Claims that negative externalities in the private valuation of genetic diversity are likely to lead to systematic underinvestment in this area [8] suggest that robust economic studies of genetic resources are needed to ensure that more socially optimal investments are made in their conservation and use in the 21st century.

Farmers are incentivized to adopt modern, high-yielding crop varieties in order to maximize their profits, often leading to the abandonment of old, traditional crop varieties. At the same time, breeding firms are likely to only conserve crop varieties they believe will allow them to generate profits through the breeding and release of new varieties. Thus, genebank managers in the public sector need to be relied upon to conserve the socially optimal amount of crop diversity. However, whether they are able to do so is dependent on both their funding, determined by governments, and the ability to roughly estimate the total economic benefits of crop diversity conservation—a task complicated by the difficulty of quantifying the non-use values of plant genetic resources, including existence, bequest and option values [9,10].

In this analysis, we apply a systems thinking approach to the valuation of genetic resources by using stated preference techniques to derive the social value of crop diversity conservation activities in the Czech Republic. By focusing on the Czech public as a whole instead of a given interest group (related to a specific crop or farmers as a group) or a specific use of genetic resources (with a demonstrated economic return), we aim to capture not just a measure of the past or potential use value of crop diversity in a narrow sense, but an approximation of the *social* value provided by genetic resource conservation, thus providing a rough hypothetical estimate of the total economic value provided to the agri-food system on a national level. This broader measure of value includes other types of value—including insurance, option, bequest and existence values—that are left out by more narrow analyses.

Methodologically, we use the double-bounded dichotomous choice stated preference method to estimate how much Czechs are willing to pay (WTP) to fund the collection and conservation of additional crop varieties over a ten-year period. Preferences are elicited through an online stated preference survey conducted in the Czech Republic (n = 1037) and its primary agricultural region, South Moravia (n = 500). Survey participants were sampled from a properly managed online panel, using quotas for region, age, gender, education, and the size of the place of residence of the respondent to ensure that both samples were representative of the Czech Republic and South Moravia, respectively.

This research focuses on the value that the Czech public places on conserving crop diversity, providing an approximation of the aggregate social benefits of plant genetic resource conservation in the Czech Republic. In contrast, most past work has instead dealt with farmer preferences. Since most countries have public conservation programs for crop diversity on the national level, the value placed by the general public on the conservation of crop varieties is also of interest.

Importantly, estimating the mean willingness-to-pay of a country's residents allows the estimation of the aggregate WTP for crop conservation on a country-wide level. In addition, using stated preference methods to focus on the general public makes it possible to capture the "passive use values" of crop diversity, of importance for the public, as well as for farmers. These include bequest and existence values, the option/insurance value of genetic resources (associated with the potential use of crop diversity to help respond to future shocks and needs), as well as the cultural value of crop varieties, as embodied by heritage fruit trees and their associated uses in the making of jams, preserves and brandies, for example. Furthermore, to obtain an appropriate level of financial support, it is also necessary to obtain rigorous estimates of the diverse economic values of crop diversity in order to justify expenditures on the conservation of these genetic resources. This analysis represents a first substantive step towards that goal in the context of the Czech Republic.

2. Literature Review

A number of studies have used the contingent valuation approach to elicit preferences related to the conservation of crop genetic resources or potential usage of traditional varieties. The main goal of these studies was to derive the monetary values and hence social benefits associated with these conservation activities or optional uses that are not directly dependent on their past use in breeding new, improved crop varieties. Past studies have addressed either preferences of agents on the supply side, or on the demand side of the economy (consumers). The former studies aimed to determine the decisions/preferences of farmers or cultivators related to specific technologies or techniques, including their interest in using traditional or environmentally friendly, but less productive varieties. The latter group of studies instead focused on the preferences of individuals behaving as consumers. These include studies that elicited preferences for rare or traditional products, such as apples or salami, while the others examined the acceptability of specific public conservation programs.

Starting with the former body of research, Poudel and Johnsen (2009) used an open-ended elicitation format to estimate the willingness of Nepalese farmers to pay for the conservation of rice landraces, finding a mean willingness to pay of US$4.18 for in situ and US$2.20 for ex situ conservation per landrace per year [11]. However, more recent studies have used close-ended questions that provide a discrete bid and ask the respondent if they accept or do not accept the offer, as (the open-ended elicitation approach, which asks respondents directly how much they are willing to pay, has been criticized for not providing a realistic, market-like situation [12] and for not being incentive compatible [13]). For instance, Krishna et al. (2013) use the double-bounded dichotomous choice approach to estimate the minimum amount farm households in India would be willing-to-accept (WTA) to conserve rare, but less productive, varieties of different minor millet species [14]. They find that the mean farmer WTA values for cultivating one of the minor millet varieties on 0.10 acres of land under monocropping ranges from 148.85 to 982.21 Rupees per year, depending on the millet variety (corresponding to about $3 and $21, respectively). Another group of studies have used discrete choice experiments to analyze farmer/cultivator preferences for crop diversity as part of a wider conservation program or for their own use [15–17].

The latter group of papers aiming at consumer preferences for specific products include Rocchi et al. (2016), who use a single-bounded dichotomous choice model to elicit use and non-use values for an old Italian tomato variety, “Pomodoro di Mercatello.” The paper focuses on the population of the city where the tomato is grown and sold, and derives an estimate for WTP to “adopt” a tomato plant of the variety for conservation of 14.49 euros (a proxy for non-use value) [18]. Botelho et al. (2018) investigate whether consumers are WTP a large enough premium for traditional varieties of apples in Portugal to make it sufficiently rewarding for farmers to cultivate [19], while Balogh et al. (2016) find that consumers in Hungary have a high demand for traditional food products such as Hungarian mangalitza salami [20]. And finally, the discrete choice experiment method has even been used to elicit preferences and willingness-to-pay of the public for the presence of crop diversity within agricultural landscapes [21].

Most of these past studies have focused on the value of crop diversity on-farm [14–17], while few have used stated preference techniques to investigate the value of crop diversity held ex situ in field collections, cold storage, and cryopreservation facilities [11]. Almost all of these studies also elicit the preferences of farmers or cultivators for the conservation of crop diversity, and not those of the general public (except for the case of consumer demand for direct use—not conservation—of traditional food products and varieties). Since most countries have public conservation programs for crop diversity on the national level, however, the value placed by the general public on the conservation of crop varieties is also of interest. While members of the general population may have on average a different WTP than that of an average farmer (who directly uses crop diversity to make a living), estimating the social benefits by relying on farmers' WTP may bias the estimate. Having a WTP estimate derived from public preferences is in particular important for regions where farmers represent only a very small fraction of population, as is the case for most developed countries. In addition, using stated preference methods to elicit the WTP of the general public makes it possible to capture the "passive use values" of crop diversity—such as the option, bequest and existence values of conserving crop diversity—which are of significance for the public, as well as for farmers.

3. Materials and Methods

This study uses stated preference methods to analyze the preferences of the Czech public for conserving crop diversity and to value the conservation services provided by the Czech genebank system, which conserves crop varieties using a variety of methods, including cold storage (for wheat and other grains), in vitro (e.g., for potatoes), and in field collections (e.g., for fruit trees and wine varieties). The analysis focuses on estimating the willingness-to-pay (WTP) of the Czech population for the collection and conservation for ten years of additional traditional Czech varieties of unspecified crop types currently conserved by the Czech National Programme for the Conservation of Agricultural Biodiversity, including oil crops such as canola and sunflower, legumes such as lentils and chickpeas, vegetables, potatoes, and cereals such as barley and wheat.

3.1. Survey Method and Data

A nationally representative sample of individuals aged 18–69 in the Czech Republic was surveyed in July 2016 (n = 1037; n = 965 excluding speeders). In addition, a smaller and separate sub-sample of individuals from the agricultural region of South Moravia in the Czech Republic (n = 500; n = 463 excluding speeders) was also surveyed during the same time period. The representativeness of the samples was controlled through quota selection depending on region, age, gender, education, and size of the place of residence of the respondent (the sample proportions are not statistically different from the proportions set for each quota at the 5% level; see Table A3 in the Appendix A). The quotas were satisfied for each of the sub-samples independently. The questionnaire was tested and developed through a qualitative pre-survey, and was also further tested on a representative sample of the Czech adult population (ages 18–69) in a three-day pilot (n = 175). The main wave of the survey was administered over a 5-day period in July 2016.

Data were collected with the Computer-Assisted Self Interviewing (CASI) method, using an online survey instrument to allow for more flexible experimental designs and randomizations. The survey instrument was programmed and maintained by the Charles University Environment Centre, as were the output data matrices making up the database of results. A professional market research firm (STEM/MARK) was hired to incentivize respondents to answer the survey, to manage the quotas, and to carry out the data collection in line with the standards of the international research association ESOMAR.

Respondents were sampled from an internet panel, properly managed by Český Národní Panel. Table 1 lists descriptive statistics for the sample for a selection of the socioeconomic and attitudinal variables used as covariates in the analysis, including residence in a village, whether the respondent personally cultivates edible plants for own consumption, has an agricultural job, regularly visits farmers' markets, had heard of genebanks, or believed that adapting the Czech agriculture sector to climate change was important.

Table 1. Descriptive statistics for the survey sample (excluding speeders).

	General Population (n = 965)	South Moravia (n = 463)
Personal income (mean)	$611	$664
Income not reported	4%	6%
High education	14%	15%
Age	42.9	42.6
Male	49%	46%
Village residence	27%	27%
South Moravia	11%	100%
Gardener	63%	67%
Employment in agricultural sector	2%	2%
Farmers' market	14%	6%
Has heard of genebank	58%	60%
Adapting agriculture to climate change important	52%	53%

All interviews in which the respondent took less than the 48% median time for a given sub-sample were excluded from the final sample as speeders (about 7% of the sample) to control for respondents who answered questions too quickly without carefully reading them (see Table A1 in Appendix A), in total leaving 965 valid observations for the Czech representative sample and 463 for the South Moravian sample. In addition, we also defined samples where protestors were excluded (see Table A2 in Appendix A). Protestors were defined as those who indicated that they were not willing to pay to conserve crop diversity in both the initial and follow-up contingent valuation question, and additionally indicated in a following debriefing question that they did not trust the information provided; desired to have more information to make their decisions; or wrote in the comments that they had made a mistake in clicking the status quo. Excluding speeders, about 8.5% of the Czech representative sample and about 9.3% of the S. Moravian sub-sample were defined as protestors.

3.2. Survey Instrument

The survey instrument was drafted in English, translated into Czech, and programmed into an online format. The survey questionnaire included three other choice experiments (each with accompanying explanatory text) in addition to the general crop diversity experiment that provided the data for this paper. The structure of the survey instrument is outlined below:

- Questions to confirm the quota filling and screening questions
- Questions about values and attitudes towards crop diversity
- Introductory text about crop diversity and its importance
- Choice tasks
- Sociodemographic information and other attitudinal questions

Before the choice questions, we provided information about the concept of crop diversity and the role of genebanks in conserving crop diversity. We also introduced the relevant public national program (see Appendix B for an English version of the text provided in Czech to survey respondents before the start of the contingent valuation questions.). Knowing that any information provided may affect the decision-making of the respondents, we provided only basic, neutral and factual information to describe the program. Such factual information is needed to allow the survey participants to make well-informed decisions. Further, the provision of such basic, neutral and factual information is of particular importance for non-market goods such as crop diversity conversation, where respondents may not be familiar with what they are valuing. For example, Johnston et al. (2017) highlight the need for a "balanced and effective presentation of information," while McFadden and Train (2017) discuss a number of stated preference studies that rely on the presentation of information and even suggest that greater familiarity can lead to respondents making more consistent and predictive choices, helping to reduce hypothetical bias [22,23]. The exact wording was comprehensively pre-tested during the pre-survey in order to minimize potential information bias. Stated preference practitioners have even gone so far as to hold a "valuation workshop" in the case of other unfamiliar goods (such as coldwater corals), in which participants observed a 30-min Powerpoint presentation and had an opportunity to ask questions [24]. An alternative to our approach would have been to use an information treatment provided to a sub-sample; however, given the many existing studies that have already investigated the question of the effect of providing information on respondent WTP [25–28], we opted to follow the standard practice of providing the same basic information set to all respondents, as guided by Johnston et al. (2017).

In addition, we asked respondents whether or not they had heard of genebanks before in order to determine past familiarity with crop diversity conservation before the survey took place. About 57.5% of respondents (and 60.2% in the South Moravia region) had heard of genebanks. This analysis and question was used to determine how past familiarity with genebanks affected respondents' WTP for the crop diversity conservation program.

After this introductory text, respondents were then asked whether they would be willing to contribute a certain amount of money to a public fund for the collection and conservation of a specific number of varieties of unspecified Czech crops for a 10-year period that had not been conserved elsewhere, and in a scenario where if the respondent does not contribute, the varieties run the risk of being irretrievably lost. The potentially conserved crops included fruit trees, hops, wheat, grapevine, oilseed (e.g., canola and sunflower), legumes (e.g., lentils), potatoes, and the diversity of other crops that are currently stored by the Czech National Programme.

Two attributes were used in this experiment, which was analyzed using a double-bounded dichotomous choice model: The one-time paid cost with values of 50, 100, 200, 300, and 500 Kč (corresponding to about $2, $4, $8, $12.5, and $21), and the number of currently unconserved, "unspecified" crop varieties in the Czech Republic to be conserved for 10 years by the hypothetical program, with the levels of 5, 10, 15, 25, and 35 varieties conserved. The bid values and the number of varieties were attributed to each respondent at random and independently.

Given that there were only two attributes included in this experiment, each with five levels (yielding 25 total combinations of cost and number of varieties conserved), it was possible to use a full factorial design. While the number of varieties remained the same in the second following discrete choice question, the bid was doubled or divided by two, depending on the preceding choice question.

3.3. Econometric Approach

We use the double-bounded dichotomous choice elicitation format, which first asks the respondent whether he or she is willing to pay a given amount for the conservation of a given number of unconserved crop varieties, and then asks a follow-up question with a higher bid (if the initial response was "yes") or a lower bid (if the initial response was "no"). This approach falls under the general category of binary choice models, which are designed to model the "choice" between two discrete alternatives (pay or not pay for the option), and models the data as utility-maximizing responses within a random utility framework [29,30]. This approach has been shown to offer asymptotically greater statistical efficiency than the simpler single-bounded dichotomous choice method, as shown by Hanemann et al. (1991) [31]. This approach also has the advantage that it can be analyzed both with the double-bounded responses and by using the single-bounded dichotomous choice model (by simply ignoring the answers to the second question).

The data from the experiment were analyzed using the maximum likelihood estimator associated with the double-bounded dichotomous choice approach. We can describe this estimator as follows (using the same framework as employed by Hanemann et al. (1991)).

In the double-bounded dichotomous choice (DBDC) approach, we start with a first bid B_i. If the respondent responds "yes" to this first bid, the second bid ($B_i{}^u$) is larger than the first bid ($B_i < B_i{}^u$). If the respondent responds "no" to the first bid, however, the second bid (Bid) is some number lower than the first bid (Bid < B_i). The four outcomes of the DBDC experiment are thus "yes-yes," "yes-no," "no-yes," and "no-no." We can denote the probabilities of these outcomes as π^{yy}, π^{yn}, π^{ny}, and π^{nn}, respectively. Using these probabilities, and assuming that the respondents are utility-maximizing, we can express the formulas for the likelihoods.

First, for π^{yy}, the probability that the respondent responds "yes-yes:"

$$\pi^{yy}\,(B_i, {B_i}^u) = \Pr\{B_i \le \max \text{WTP and } {B_i}^u \le \max \text{WTP}\}, \quad (1)$$

$$=\Pr\{B_i \le \max \text{WTP} \mid {B_i}^u \le \max \text{WTP}\}\ \Pr\{{B_i}^u \le \max \text{WTP}\}, \quad (2)$$

$$=\Pr\{{B_i}^u \le \max \text{WTP}\} = 1 - G({B_i}^u;\, \theta), \quad (3)$$

this follows from the fact that if $B_i < {B_i}^u$, $\Pr\{B_i \le \max \text{WTP} \mid {B_i}^u \le \max \text{WTP}\} \equiv 1$.

In the case of "no-no," we can similarly use the information that Bid < B_i to conclude that $\Pr\{\text{Bid} \le \max \text{WTP} \mid B_i \le \max \text{WTP}\} \equiv 1$, and express the probability that the respondent responds "no-no" as:

$$\pi_{nn}\,(B_i, \text{Bid}) = \Pr\{B_i > \max \text{WTP and Bid} > \max \text{WTP}\} = G(\text{Bid};\, \theta), \quad (4)$$

for "yes-no," it holds true that $B_i < B_{iu}$, giving us:

$$\pi_{yn}\,(B_i, {B_i}^u) = \Pr\{B_i \le \max \text{WTP} \le {B_i}^u\} = G({B_i}^u;\, \theta) - G(B_i;\, \theta), \quad (5)$$

and finally, for "no-yes," it holds true that $B_i < {B_i}^u$, giving us:

$$\pi_{ny}\,(B_i, \text{Bid}) = \Pr\{B_i \ge \max \text{WTP} \ge \text{Bid}\} = G(B_i;\, \theta) - G(\text{Bid};\, \theta). \quad (6)$$

The second bid in the last two examples (π_{nn} and π_{ny}) allows the placement of an upper and lower bound on the respondent's unobserved true WTP, while the second bid in the first two examples (π_{yy} and π_{nn}) allows us to improve the single bound by raising the lower bound or lowering the upper bound.

Given a sample of N respondents and bids of B_i, ${B_i}^u$, and Bid (used for the ith respondent), we obtain the following log-likelihood function, with d_i^{yy}, d_i^{nn}, d_i^{yn}, and d_i^{ny} being binary-valued indicator variables equal to one for the positive response and to zero otherwise:

$$\ln L^D(\theta) = \sum_{i=1}^{N}\{d_i^{yy}\ln \pi^{yy}(B_i, B_i^u) + d_i^{nn}\ln \pi^{nn}\left(B_i, B_i^d\right) + d_i^{yn}\ln \pi^{yn}(B_i, B_i^u) + d_i^{ny}\ln \pi^{ny}\left(B_i, B_i^d\right)\} \quad (7)$$

The Maximum Likelihood estimator for the double-bounded model ($\hat{\theta^D}$) and the interval data is used to maximize the log-likelihood. In this case, the asymptotic variance-covariance matrix for $\hat{\theta^D}$ is given by:

$$V^D(\hat{\theta^D}) = \left[-E\frac{\partial^2 \ln L^D(\hat{\theta^D})}{\partial\theta\,\partial\theta'}\right]^{-1} \equiv I^D(\hat{\theta^D})^{-1}. \quad (8)$$

The data were analyzed with this model framework using SAS/STAT software.

4. Results

The primary objective of this work was to determine the value placed on the conservation of Czech crop diversity by the Czech public. As the main result, we provide the regression results for the double-bounded dichotomous choice analysis below for the Czech general population sample (excluding speeders) in Table 2 (left panel). We assume the disturbances follow the Weibull distribution, as it minimizes the information criteria and maximizes the log-likelihood for our data across all standard distributional forms.

Table 2. Estimation results for double-bounded dichotomous choice data, by sub-sample.

Variable	Czech Sample		South Moravian Sample	
	Coeff.	**Std. Errors**	**Coeff.**	**Std. Errors**
Intercept	5.217 ***	0.082	5.128 ***	0.160
Varieties	0.006 *	0.003	0.015 *	0.008
Scale	1.361	0.055	1.477	0.091
Weibull Shape	0.735	0.030	0.677	0.041
Number of obs.	965		463	
Log-likelihood	−1277.43		−596.04	
Implied mean WTP for the program, in Kč (US$)	223 Kč ($9.08)		221 Kč ($8.98)	

Note: * and *** represent 10% and 1% significance levels, respectively. Weibull distribution assumed.

The number of crop varieties to be conserved (“Varieties”), is found to be weakly significant, but still positive—indicating that the probability to choose the program is increasing with the size of the program. However, respondents’ preferences are strongly in favor of the program itself, as the intercept is positive and much larger than the coefficient for Varieties and is strongly significant. The intercept measures the marginal utility for a conservation program regardless of how many crop varieties would be conserved. The mean willingness-to-pay is found to be 223 Czech crowns (Kč), equivalent to $9.08 (using the exchange rate from 23 July 2016 of 24.62 Kč per dollar, retrieved from www.xe.com immediately after the period of the study.). The WTP is increasing in the number of crop varieties, by between 1 and 2 Kč per additional variety conserved (~$0.05), and implies that the total WTP is increased by 26 Kč ($1.07, by ~12%) for the average number of varieties offered in the valuation experiment (18) and by 43 Kč ($2.20, by ~24%) for the highest number of varieties to be conserved as a part of the contingent scenario (35). The WTP distribution is right-skewed, implying median values of 112 Kč ($4.55) for a conservation program.

The results for the South Moravian sample are presented in the right panel of Table 2, and they are qualitatively similar to the results for the country-representative sample. Both the intercept and the “Varieties” variable are positive and significant. The intercepts for the two models estimated on two different samples are not statistically distinguishable from each other (Wald = 0.245, p-value = 0.62 for the intercepts and Wald = 1.114, p-value = 0.29 for the Varieties variable). The mean willingness-to-pay for a conservation program is 221 Kč ($8.98). For the average number of varieties respondents were WTP about 30% more—in absolute terms 68 Kč ($2.78)—when compared with their WTP for the program alone.

The implied mean WTP is 223 Kč ($9.06) and this value only captures benefits for the conservation program, regardless of the number of varieties. We show in Figure 1 below how mean WTP changes based on the number of varieties conserved by the program. Note that respondent WTP was more sensitive to the number of varieties conserved in the South Moravian sample, where mean WTP increases to 373 Kč ($15.16) for the maximum number of varieties, while only increasing to 278 Kč in the general Czech representative sample.

Excluding respondents who we identified as protestors produces a more generous estimate of WTP that is only about 5% larger in absolute terms 236 Kč ($9.59). Utilizing less information from the single-bounded dichotomous choice elicitation, we obtain a mean WTP of 136 Kč ($5.52) and 182 Kč ($7.39) respectively, see Table 3.

Including respondents we identified as protestors provides a conservative WTP estimate. As a robustness check we also estimate the models where protestors are excluded (Table A6 in the Appendix A), and then both versions of the single-bounded dichotomous choice model (Tables A4 and A5 in the Appendix A). We define protestors as respondents who chose the status quo for every choice task and further indicated that they did not trust the information provided, desired to have more information to make their decisions, or made a mistake in the options they selected. These results are reported in Table 3. The full results for these regressions can be found in the Appendix A.

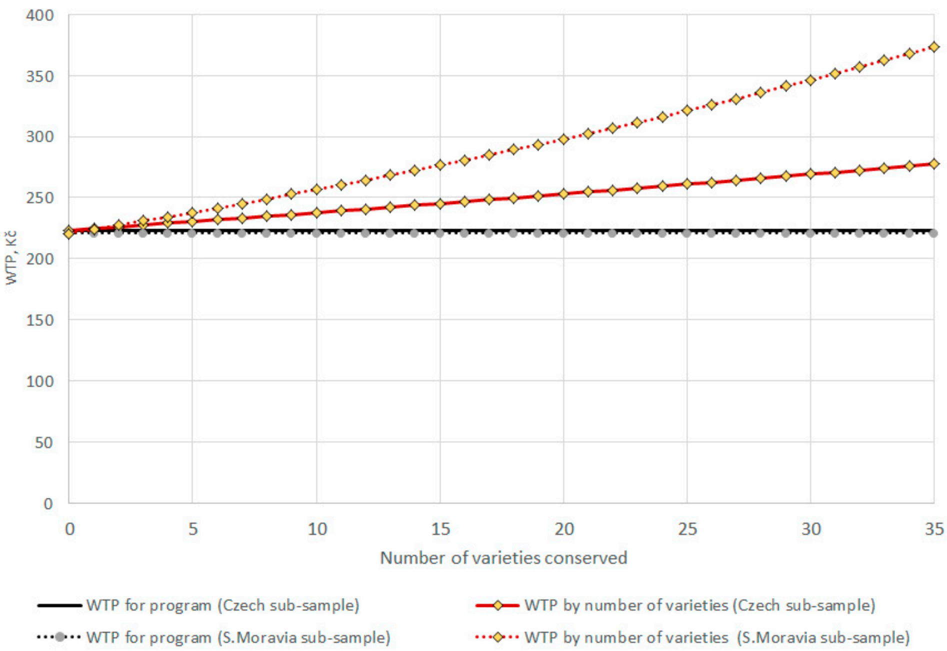

Figure 1. WTP for the program by number of varieties conserved.

Table 3. Mean WTP for single- vs. double-bounded dichotomous choice model, including or excluding protestors [1].

Model	Mean WTP
Single-bounded dichotomous choice, protestors included	136 Kč (37.96)
Single-bounded dichotomous choice, protestors excluded	182 Kč (39.14)
Double-bounded dichotomous choice, protestors included [2]	223 Kč (9.96)
Double-bounded dichotomous choice, protestors excluded	236 Kč (9.98)

[1] Note: Standard errors in parentheses. [2] DBDC with protestors included is the preferred model, with the other alternatives included as robustness checks.

Excluding protestors naturally increases the mean WTP estimate as all protesters are, by definition, respondents who did not agree to pay for a program. After excluding the protesters, the mean WTP value becomes much higher for the single-bounded model (by 34%) than for the double-bounded data (increase by 6% only), since the mean estimate for the double-bounded data is more affected by the acceptance of a higher bid. Since SB-DC uses less information and since protesting respondents always refused paying for the program, these specifications provide a conservative WTP estimate.

4.1. Aggregate WTP Estimation

The mean WTP figure from the Czech representative sample was multiplied across the Czech population ages 18–69 (about 7.5 million), using population figures obtained from the Český statistický úřad (the Czech Statistical Office) website (www.czso.cz) for 2015, yielding an aggregate willingness-to-pay for general crop conservation in the Czech Republic of 1.67 billion Kč, equivalent to about $68 million. This estimate is more than 4.5 times higher than the cost of maintaining the current Czech crop diversity holdings for ten years, estimated at 360 million Kč, equivalent to about $14.6 million (Pers. communication, V. Holubec; budget documentation available at http://genbank.vurv.cz/genetic/nar_prog_rostlin/Dokumenty/Zasady_GZ_2017.pdf). The same calculation for South Moravia, with a population of about 830,000, yields an aggregate WTP for the region of about $7.4 million for the conservation of crop diversity. These benefits are derived from the WTP for a crop diversity conservation program, regardless of how many crop varieties would be conserved by the program. Each newly conserved crop variety would increase the total benefits by between $420,000 and $520,000. Considering the maximum number of crop varieties that might be newly conserved in our experiment (35), our estimate of the total welfare benefits would increase by $16.4 million to a total of $84 million.

4.2. Augmented Model

Next, we investigate which population segment is more likely to agree with the program and thus pay for it. Since people who are familiar and have had prior knowledge about crop diversity conservation and genebanks may have different preferences for crop conservation, we first investigate this question (results presented in Table 4). We find that 58% of respondents (60% in Southern Morava sample) had heard about genebanks and almost all who had heard about genebanks had also heard about climate change problems (still, 39% who have heard about climate change had not heard about genebanks). Those who had heard about genebanks were more likely to be males, older than 40, and residing in a city with more than 100,000 inhabitants. Respondents who gardened or believed that it is important to adapt the Czech agriculture sector to climate change also tended to be more familiar with genebanks.

Table 4. Determinants of familiarity with genebanks, logit model for the Czech representative sample.

Variable	Coeff.		Std. Error	Marginal Effects	
Income	0.132		(0.099)	0.069	
Income information not provided	−0.214		(0.428)	−0.044	
Male	0.826	***	(0.151)	0.171	***
Village	−0.118		(0.175)	−0.024	
City	0.472	**	(0.188)	0.098	**
S. Moravia	−0.247		(0.225)	−0.051	
Low education	−0.725	***	(0.238)	−0.150	***
Medium education	−0.201		(0.240)	−0.042	
Age < 30	−1.363	***	(0.246)	−0.282	***
Age 30–39	−0.898	***	(0.238)	−0.186	***
Age 40–49	−0.351		(0.242)	−0.073	
Age 50–59	−0.068		(0.235)	−0.014	
Student	0.101		(0.314)	0.021	
Employed in agriculture sector	0.076		(0.577)	0.016	
Gardener	0.438	***	(0.155)	0.091	***
Visits farmer markets	0.304		(0.216)	0.063	
Important to adapt agr. to CC	0.514	***	(0.146)	0.106	***
Protestor	−0.264		(0.254)	−0.055	
Constant	0.220		(0.341)	0.000	***
Number of obs.	965				
Log-likelihood	−579.86				

Note: ** and *** represent 5% and 1% significance levels. Income of respondent expressed in 10,000 Kc a month after-tax.

We now run an extended DBDC model that includes the variable "heard of genebank" as a proxy for familiarity, to investigate whether having knowledge of genebanks led to a greater WTP for the crop diversity conservation program described in the experiment. We find that those who are familiar with the crop conservation program and genebank are in fact also more likely to agree with the presented scenario and hence to pay more for it. The effect of familiarity is similar to that of believing that it is important that the Czech agriculture sector be adapted to climate change. In the sample representative of the general Czech population (left side in Table 5), females, income, and those aged below 40 or in her 50's have all positive effect on WTP. We do not find however this association in the South Moravian sample, in that only people living in cities or gardeners are found to be willing to pay more for crop conservation. Respondents from the South Morava agricultural region are also more sensitive to the number of crop varieties conserved, while Czech respondents on average have demand for the conservation program regardless how many crop varieties are conserved by the program.

Table 5. Estimation result for double-bounded dichotomous choice model augmented by socio-economic variables, the interval-data estimation assuming Weibull distribution.

	Czech Sample			South Moravian Sample		
	Coeff.		**Std. Err.**	**Coeff.**		**Std. Err.**
Intercept	4.2603	***	0.2194	3.7786	***	0.3585
Varieties	0.0047		0.0032	0.0137	*	0.0074
Income	0.1938	***	0.0673	0.0526		0.0867
Income information not provided	0.1798		0.2992	−0.0071		0.3687
Male	−0.2197	**	0.1076	0.1218		0.1735
Village	−0.0314		0.1216	0.2131		0.194
City	−0.0829		0.1288	0.3398	*	0.188
Primary education	−0.0051		0.1161	0.1053		0.1813
Tertiary education	0.0736		0.1637	−0.2707		0.2518
Age 18–29	0.3699	**	0.1821	0.212		0.3011
Age 30–39	0.3305	**	0.1656	0.0014		0.2691
Age 40–49	0.1676		0.1619	0.02		0.2602
Age 50–59	0.2689	*	0.158	−0.2277		0.2694
Childless	0.0408		0.1316	−0.0637		0.2115
Employed in agriculture sector	0.672		0.4793	0.6188		0.5186
Gardener	0.1755		0.1082	0.3115	*	0.1738
Visits farmer markets	0.1407		0.1467	0.2481		0.3476
Familiar with genebank	0.3341	***	0.1051	0.6524	***	0.1743
Important to adapt agr. to CC	0.4373	***	0.1013	0.7575	***	0.1641
Scale	1.3203			1.3766		
Weibull Shape	0.7574			0.7264		
Log-Likelihood	−1248			−567.64		
No. of obs.	965			463		

Note: *, **, and *** represent 10%, 5% and 1% significance levels, respectively. Income of respondent expressed in 10,000 Kc a month after-tax.

We find in the general Czech representative sample that gardeners were WTP about 20% more, and males about 20% less, while those who stated that they believed it was important to adapt Czech agriculture to climate change were WTP about 55% more for crop diversity conservation. Those with higher personal income were also found to be WTP more for the crop conservation program. The results for the South Moravia sub-sample were roughly the same as for the Czech sub-sample, although gender and personal income were not found to be significant in determining WTP among these respondents.

We find that those who had "heard of genebanks" before were willing to pay about 40% more for the program than those who had not. This variable can be considered a proxy for familiarity with crop diversity conservation, thus showing that having past knowledge and information about similar programs was associated with a greater WTP for the hypothetical future program described in the survey.

5. Discussion

The data used in this research were collected with the Computer-Assisted Self Interviewing (CASI) method, using an online survey instrument. The CASI online survey method was selected because of its lower cost (enabling a higher sample size), higher efficiency, and improvement of the response rate, reducing the impact of response bias. In addition, computerized methods of data collection have been shown to have a positive effect on data quality. There are fewer interviewer and respondent errors, since a computerized questionnaire can disallow certain types of mistakes, and it has also been shown that respondents are often less inhibited in a computer-assisted self-interview, since their answers are completely anonymous [32]. Computerized surveys also enable the use of more flexible designs with more easily randomized treatments and screening questions. Another benefit is the possibility to have the data automatically entered into a database.

The online survey method used for data collection in this study does however have some potential biases. First, it reaches only those who have access to a computer and the internet, screening out a group of potential respondents. This is not likely to have had a large biasing effect in the case of this study, however, as internet access has been rapidly increasing in the Czech Republic in recent years, with more than 82% of households having internet access in 2016 [33]. Second, it also selects for individuals who elect to participate in the online survey panels used by the market research firm selected for this study. In spite of these potential biases, CASI was deemed to be the best approach for data collection for this study.

Several other biases may have arisen from the use of stated preference methods, such as strategic bias, information bias, or hypothetical bias [34]. However, steps were taken to mitigate these potential biases. For example, information was provided to try to lessen the impact of information bias by educating the respondents about crop diversity during the survey—although we did find that those who had heard of a genebank before were willing to pay significantly more than the portion of the sample that had not, and the results of stated preference studies are likely to be at least somewhat sensitive to how background information is presented to the respondents. Strategic bias may also have affected the results; however, a review of comments revealed that many of the respondents took the survey seriously and accounted for their budget constraint when making the decision. Last, while hypothetical bias may have had an effect, most Czechs have at least some experience with the crop varieties included in the survey, and thus are not likely to have been overly affected by this source of bias.

While stated preference methods have been criticized by some economists [35], a NOAA panel convened by the U.S. government and co-chaired by Nobel Laureates Kenneth Arrow and Robert Solow concluded that the general approach is appropriate for estimating the value of environmental goods and services, and that "CVM studies can produce estimates reliable enough to be the starting point of a judicial or administrative determination of natural resource damages, including lost passive values" [36,37], supporting the validity of the methodological approach taken in this study. More recently, Johnston et al. (2017) also affirm that stated preference methods may be used as the basis for decision-making by governmental and nongovernmental organizations if best practices are followed [25].

5.1. The Impact on WTP of the Information Provided

The results of the double-bounded dichotomous choice regression with socio-economic variables included in Table 5 show that those more familiar with crop diversity conservation (i.e., had heard of genebanks) were willing to pay about 40% more for a hypothetical conservation program, indicating that the provision of information (having the result of increasing familiarity with the program) may have had the effect of biasing WTP upwards. This finding has been echoed in other similar research that has found that those who are more aware of the good/service to be valued are more likely to have a higher WTP [38]. On the other hand, other research on WTP for climate change has found no impact of providing additional information [39].

The higher WTP of these individuals (who had previous knowledge of genebanks) may have also been a result of other correlated factors, however, given that the heterogeneity in the general Czech population in terms of willingness-to-pay for additional conservation of crop varieties had more to do with specialized knowledge, beliefs and habits (whether or not the respondents thought adaptation in the agriculture sector was important, or gardened, for example) than general socioeconomic variables. We provide a logit analysis of the determinants of familiarity with genebanks in Table 4, and find that respondents that were gardeners, male, older, from cities, and more highly educated (among other factors) were more likely to have heard of genebanks.

It is important to highlight as well that providing basic information that is both neutral and factual is considered standard practice in stated preference research. In addition, the objective of this analysis was to determine how much the public would be WTP for the conservation of crop diversity conditional upon respondents possessing some basic information about such a program and its importance. The policymaker would like to know the preferences of a minimally informed public, not those of an ignorant one. Furthermore, basic information about crop diversity and its conservation similar to that included in the survey could be easily provided to the Czech public through an informational program sponsored by the government at very low cost, raising the population's awareness of the issue to the level of the surveyed population.

Furthermore, it is important to note that unfamiliarity with the good or service to be valued can also bias the results of an analysis, as shown by Lusk and Norwood (2009), who find that respondents understated their preferences for relatively unfamiliar goods when compared to their actual behavior in the field [40]. Thus, even providing no contextual information can have a biasing effect. One way to address this tradeoff is the so-called "inferred valuation" approach, as Lusk and Norwood suggest [41]. Another would be to utilise a split-sample design to investigate whether the provision of basic information about the value of crop diversity increased respondent WTP when compared with respondents who were provided with no context. Both of these approaches represent interesting avenues for further research.

5.2. Policy Implications

The main finding of this research is that Czechs, if provided with basic information about crop diversity and its importance, would be willing to pay in aggregate about $68 million dollars for general crop conservation over the next 10 years—about 4.5 times more than the current conservation costs of the Czech genebank system. We use the mean WTP figures for general crop conservation resulting from the double-bounded dichotomous choice model analysis as our primary result because this model has been shown to use more information and be more statistically efficient than the single-bounded approach (Hanemann et al., 1991). In addition, we include protestors in order to provide a more conservative estimate.

We also present alternative aggregate WTP figures calculated using the single-bounded dichotomous choice (SBDC) model, with and without protestors included, and the double-bounded dichotomous choice (DBDC) model results with protestors excluded. Table 6 presents these results along with the associated benefit-cost ratios generated by comparing the estimated aggregate social benefits to the costs of conservation. From this further analysis we produce aggregate WTP estimates ranging from $42 million to $71 million—and with benefit-cost ratios ranging from about 3 to 5. We also note that the benefit-cost ratio exceeds two even if median WTP figures are used.

Regardless of the model used (and whether or not protestors are excluded), the general finding of the study remains the same: Czechs are willing to pay several times more than the current levels of funding of the Czech genebank system for the conservation of the country's crop diversity. The main and robust policy implication from this result is that the national genebank system produces social benefits in excess of the operational costs, and that the Czech public would support an increase in funding of the Czech plant genetic resources conservation program, if such an increase were able to secure the conservation of currently unconserved crop varieties in the country.

Table 6. Aggregate WTP figures and benefit-cost ratios for the Czech sub-sample [1].

Model	Estimated Aggregate WTP	Benefit-Cost Ratio
SBDC, protestors included	$42 million	2.8
SBDC, protestors excluded	$55 million	3.8
DBDC, protestors included [2]	$68 million	4.6
DBDC, protestors excluded	$71 million	4.9

[1] These values are based on the "pure" WTP for a crop diversity conservation program, regardless of how many varieties would be newly conserved in a genebank. Total estimated benefits would be even higher by between $3.5 million (DBDC without protestors) and $3.7 million (DBDC with protestors). Costs were provided by Dr. Vojtech Holubec of the Crop Research Institute. [2] Note: DBDC with protestors included is the preferred model, with the other alternatives included as robustness checks.

6. Conclusions

By taking a systems approach to valuation (and focusing on the Czech public), this experiment provides a broader welfare measure of the value of crop diversity conservation in the Czech Republic than an approach focused strictly on farmers or plant breeders. It also captures the non-use values associated with genetic resources, such as insurance and option values, existence value, and bequest value. On average, Czechs were willing to pay $9 to collect and conserve additional crop diversity over a ten-year period, corresponding to an aggregate WTP in the Czech Republic of at least $68 million—about 4.5 times more than the costs of running the entire Czech genebank system for ten years. This result indicates that Czechs (if provided with basic information about crop diversity and its benefits) would be willing to pay more to expand the country's crop diversity conservation program through the collection and conservation of additional crop varieties, and highlights the social value of the Czech Republic's agricultural heritage, a resource important for future efforts to adapt the country's agricultural sector to climate change.

It must be noted that the public value for a crop diversity conservation program estimated in this analysis does not represent the preferences of the Czech public *per se*, but rather a representative sub-set of the Czech population after being exposed to a short and factual set of information regarding crop diversity conservation and its benefits. (Information—as provided in our contingent scenario—could relatively easily be provided to the public through an informational campaign run by the government or an NGO). This information—which could relatively easily be provided to the public through an informational campaign run by the government or an NGO—was included in our study because some participants were not familiar with ongoing public agrobiodiversity conservation efforts in the Czech Republic, to provide context, and to limit the impacts of unfamiliarity on the surveyed population. However, an interesting question for future research would be to identify the impacts of providing such information on respondents' WTP, through a split-sample design where only a sub-set of respondents are provided with background information and the others are not provided with any information or context. A further approach that could be used to reduce this source of bias is the "inferred valuation" approach of Lusk and Norwood (2009) [41].

This straightforward and relatively simple approach to estimating the social value of genetic resources could be used in other countries as well to determine how well the current investments into the collection and conservation of crop diversity match the willingness of the public to pay for them. This information could be particularly useful in some European countries like Hungary, where uncollected crop varieties are likely still present in diverse home gardens [15], or in developing countries in Africa, Asia and Latin America. In such cases, applying a systems thinking approach to estimating the social benefits associated with crop diversity conservation as derived here from a stated preference study may be compared with the current conservation costs of the given country's genebank system to determine if the public would support such a program and be willing to pay for the collection and conservation of additional crop varieties. If such public support exists, the social planner could use this as justification for directing further resources towards the national crop diversity conservation program budget.

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Conflicts of Interest: The authors declare no conflict of interest.

Appendix A. Additional Tables

Table A1. Sub-samples and percentage of speeders.

Sub-Sample	Mode	N (Completed)	% Speeders	N Valid
Czech Republic representative	CAWI	1037	6.9%	965
S. Moravia representative	CAWI	500	7.4%	463

Table A2. Sub-samples and percentage of protestors (after speeders excluded).

Sub-Sample	Mode	N (Completed)	% Protestors	N Valid
Czech Republic representative	CAWI	965	8.5%	883
S. Moravia representative	CAWI	463	9.3%	420

Table A3. Quota variables with target and actual figures (and deviations).

Quota Variable	Quota Set	Sample Representative to Czech Republic n = 1037		Sample with Excluded Speeders n = 965	
	Proportion	*Proportion*	*Difference*	*Proportion*	*Difference*
Gender					
male	48.4%	49.3%	0.9%	48.5%	0.1%
Education					
elementary & secondary	52.3%	53.7%	1.4%	53.1%	0.8%
secondary with A level	32.7%	32.2%	−0.5%	32.8%	0.1%
tertiary	15.0%	14.1%	−0.9%	14.1%	−0.9%
Age					
18–34	35.8%	36.5%	0.8%	35.5%	−0.2%
35–50	29.8%	27.5%	−2.3%	27.3%	−2.5%
51–69	34.4%	36.0%	1.5%	37.2%	2.8%
Residence size					
<50,000 inhabitants	40.9%	41.7%	0.7%	42.0%	1.0%
50,000 and more	28.9%	26.9%	−2.0%	26.8%	−2.0%
50,000 inhabitants	30.2%	31.4%	1.2%	31.2%	1.0%
Regions					
Capital City of Prague	12.6%	11.8%	−0.8%	11.6%	−1.0%
Central Bohemian	12.2%	12.3%	0.1%	12.4%	0.2%
South Bohemian + Pilsen	11.5%	12.0%	0.5%	12.2%	0.7%
Karlovy Vary + Usti n.L.	10.4%	10.0%	−0.4%	10.2%	−0.2%
Liberec + H.Kralove + Pardubice	14.2%	14.8%	0.6%	14.9%	0.7%
Olomouc + Zlin + Vysocina	16.4%	17.0%	0.6%	16.7%	0.3%
Moravskoslezský	11.2%	10.7%	−0.5%	10.6%	−0.6%
Jihomoravský	11.5%	11.5%	0.0%	11.4%	−0.1%

Table A4. SBDC regression results for the Czech representative population, protestors included [1].

Variable	DBDC Estimates
Intercept	0.410 *** (0.142)
Varieties	0.005 (0.004)
Bid	−0.003 *** (0.000)
Number of obs	965
Log-likelihood	−640.02

[1] Note: *** represent 1% significance levels, respectively; standard errors in parentheses.

Table A5. SBDC regression results for the Czech representative population, protestors excluded [1].

Variable	DBDC Estimates
Intercept	0.532 *** (0.150)
Varieties	0.006 (0.005)
Bid	−0.003 *** (0.000)
Number of obs	883
Log-likelihood	−598.07

[1] Note: *** represent 1% significance levels, respectively; standard errors in parentheses.

Table A6. DBDC regression results for the Czech representative population, protestors excluded [1].

Variable	DBDC Estimates
Intercept	5.334 *** (0.080)
Varieties	0.007 ** (0.003)
Scale	1.256 (0.050)
Weibull Shape	0.796 (0.032)
Number of obs.	883
Log-likelihood	−1224.09

[1] Note: ** and *** represent 5% and 1% significance levels, respectively; standard errors in parentheses.

Appendix B. Introductory Text on the Value of Crop Diversity

What is the meaning of crop diversity and why is it important?

The concept of crop diversity can be easily explained by the fact that a given crop is not uniform, but is made up of many different varieties that vary significantly and may have unique characteristics.

For example, the image below shows one bean variety (source: Global Crop Diversity Trust Flickr).

In contrast, the following picture shows many different varieties of beans.

Crop diversity is of economic value and helps to ensure food security. It is of particular value for the following two reasons:

- Genetic diversity in different crop varieties is valuable for breeding new, improved varieties of crops that are more profitable and resilient.
- Crop varieties also provide benefits and value for farmers who grow them, as well as those who then consume or otherwise use the resulting products.

Crop varieties are stored in "genebanks," which are the places where the seeds, tubers and samples of various crops are conserved and maintained.

In the Czech Republic, crop diversity is maintained by the public National Programme for the Conservation and Use of Genetic Resources of Plants Important to Nutrition and Agriculture.

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