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Estimating the Value of Crop Diversity Conservation Services Provided by the Czech National Programme for Agrobiodiversity

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Abstract:
We estimate the willingness-to-pay (WTP) for conserving crop varieties for ten years in the Czech Republic using a double-bounded dichotomous choice model to analyze data collected with an online contingent valuation survey administered to a main country-wide sample of 1037 respondents and a smaller sub-sample of 500 representative of the agricultural region of South Moravia. 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 5% for every ten varieties conserved, implying total welfare benefits of $80 million for a program conserving the maximum number of 35 additional crop varieties. The study reveals the previously unmeasured social benefits of crop conservation activities in the Czech Republic, and 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
JEL: Q18, Q51, Q57

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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 distribution of these varieties in the developing world helped to launch the Green Revolution, along with the increased use of fertilizers and pesticides (Hedden 2003), and led to substantial increases in crop yield and production, a reduction in child malnourishment, and reduced crop prices in developing countries (Evenson and Gollin 2003). 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%, 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.

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 agricultural R&D spending in the U.S. (Alston *et al.* 2009), with funding for international agricultural research slowing after 1990 as well (Alston *et al.* 2006). 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 (FAO 1997).

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 (Goeschl and Swanson 2002) 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 depends 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, such as option value.[1]

This research uses stated preference techniques to derive the social value of crop diversity conservation activities in the Czech Republic. Using a double-bounded dichotomous choice experiment, we 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 in both samples 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 are representative of the Czech Republic and South Moravia, respectively.

We find that Czechs on average are willing to pay $9.08 for the conservation of additional crop varieties, which is equivalent to an aggregate, country-wide benefits of about $68 million. This figure is more than 4.5 times greater than the current projected costs of conserving the national crop diversity collection for the next ten years. The mean willingness to pay for respondents from South Moravia is not statistically different from the mean for the Czech Republic as a whole; however, the willingness to pay is larger for females, those who have heard about genebanks, who think that it is important to adapt the agriculture sector to climate change, and for those with larger incomes.

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

[1] Existence and bequest values have been analyzed as categories of non-use values (see for instance Jobsvogt *et al.* (2014), while others have considered option value as a category of non-use value (Barbier *et al.*, 1997).

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, which include bequest and existence values, the option/insurance value of genetic resources for responding 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 and then to derive the monetary values of crop genetic resources not directly dependent on their past use in breeding new, improved crop varieties. For example, Poudel and Johnsen (2009) used an open-ended bidding game approach to estimate the willingness of Nepalese farmers to pay for the conservation of rice landraces, finding a mean willingness to pay of USD 4.18 for *in situ* and USD 2.20 for *ex situ* conservation per landrace per year. However, open-ended approaches, which ask respondents directly how much they are willing to pay, have been criticized for not providing a realistic, market-like situation (Bateman *et al.* 2002) and are not incentive compatible (Carson and Groves 2007). More recent studies have used dichotomous or closed-ended questions, which provide a discrete bid and ask the respondent if they accept or do not accept the offer. Krishna *et al.* (2013) uses a 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. 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). More recently, Rocchi *et al.* (2016) uses a single-bounded dichotomous choice model to elicit use and non-use values for an old Italian tomato variety, “Pomodoro di Mercatello,” focusing on the population of the city where it 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). Other studies have utilized the discrete choice method to elicit preferences and willingness-to-pay for crop diversity conservation, such as Birol *et al.* (2006), Birol *et al.* (2007), Asrat *et al.* (2010), and Sardaro *et al.* (2016).

Most of these past studies have focused on the value of crop diversity on-farm, 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. 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. 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 a sample representative of the general population may have a smaller mean WTP per individual than a sample consisting entirely of farmers, who directly use crop diversity to make a living, calculating the mean WTP 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 elicit the WTP of the general public makes it possible to capture the “passive use values” of crop diversity – such as option or bequest value - which are of significance for the public as well as for farmers.

3. The survey and study design

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. The analysis focuses on estimating the willingness-to-pay 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 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.

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

Model	**General population (n=965)**	**South Moravia (n=463)**
Personal income (mean, std)	15,035 Kč ($610.70)	16,338 Kč ($663.60)
Income missing	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%
Heard of genebank	58%	60%
Adapting agriculture to climate change important	52%	53%

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.

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), 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). Protestors were defined as those who chose the status quo (i.e., answered no) for both choice tasks, and additionally indicated in a following debriefing qeustion 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.

3.2 The 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 question, we provided information about the concept of crop diversity, its value, the role of genebanks in conserving crop diversity and introduced the relevant public national program (see Appendix B). 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 The 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 (Luce 1959; McFadden 1974). This approach has been shown to offer asymptotically greater statistical efficiency than the simpler single-bounded dichotomous choice method (Hanemann *et al.* 1991). 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 Hanemann *et al.* (1991) employs).

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 (B_i^d) is some number lower than the first bid ($B_i^d < B_i$). 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:"

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

$$= \Pr\{B_i \leq \max \text{WTP} | B_i^u \leq \max \text{WTP}\} \Pr\{B_i^u \leq \max \text{WTP}\}$$

$$= \Pr\{B_i^u \leq \max \text{WTP}\} = 1 - G(B_i^u; \theta)$$

This follows from the fact that if $B_i < B_i^u$, $\Pr\{B_i \leq \max \text{WTP} | B_i^u \leq \max \text{WTP}\} \equiv 1$.

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

$$\pi^{nn}(B_i, B_i^d) = \Pr\{B_i > \max \text{WTP and} \quad (2)$$

$$B_i^d > \max \text{WTP}\} = G(B_i^d; \theta)$$

For "yes-no," it holds true that $B_i < B_i^u$, giving us:

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

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

$$\pi^{ny}(B_i, B_i^d) = \Pr\{B_i \geq \max \text{WTP} \geq B_i^d\} = G(B_i; \theta) - G(B_i^d; \theta) \quad (4)$$

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 B_i^d (used for the *i*th 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 equaling to one for the positive response and to zero otherwise:

$$\ln L^D(\theta) = \sum_{i=1}^{N}\{d_i^{yy} \ln \pi^{yy}(B_i, B_i^u) + d_i^{nn} \ln \pi^{nn}\left(B_i, B_i^d\right) + d_i^{yn} \ln \pi^{yn}(B_i, B_i^u) + d_i^{ny} \ln \pi^{ny}\left(B_i, B_i^d\right)\} \quad (5)$$

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

$$V^D\left(\widehat{\theta^D}\right) = \left[-E\,\frac{\partial^2 \ln L^D\left(\widehat{\theta^D}\right)}{\partial\theta\partial\theta'}\right]^{-1} \equiv I^D\left(\widehat{\theta^D}\right)^{-1} \quad (6)$$

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. 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. DBDC regression results for the Czech representative population.

Variable	DBDC Estimates
Intercept	5.217*** (0.082)
Varieties	0.006* (0.003)
Scale	1.361 (0.055)
Weibull Shape	0.735 (0.030)

Number of obs: 965
Log-likelihood: -1277.43

Note: *, **, and *** represent 10, 5 and 1% significance levels, respectively; standard errors in parentheses.

The coefficient for the "Varieties" variable, corresponding to the number of crop varieties to be conserved, is found to be significant and positive, as is the intercept representing the alternative specific constant that 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.[2] The WTP is increasing in the number of crop varieties, by about 1.22 Kč per additional variety conserved ($0.05), corresponding to only 0.5% of the WTP value for a conservation program, and implies that the total WTP is increased by 22 Kč ($0.90, by ~20%) for the average number of varieties (18) and by 43 Kč ($1.75, by ~40%) for the highest number of varieties it was possible to conserve in the experiment (35). The corresponding median values are 112 Kč ($4.50) for a conservation program, and 6.1 Kč ($0.25) per crop variety conserved, indicating a right-skewed distribution of the WTP.

[2] Using the exchange rate from July 23, 2016 of 24.62 Kč per dollar, retrieved from www.xe.com immediately after the period of the study.

The results for the South Moravian sample are presented in Table 3. Both the intercept and the coefficient for the "Varieties" variable are found again to be positive and significant. The mean willingness-to-pay for a conservation program is found to be 221 Kč ($8.98), and the intercepts for the two samples are not statistically distinguishable from each other (Wald statistic is 0.245, p-value=0.62). The WTP value for each unit of newly conserved crop variety is 1.33 Kč ($0.05), with an increase in the total WTP of 24 Kč ($0.97) for the average number of varieties (18). Again the coefficients for the two samples are not statistically different (Wald statistic is 1.114, p-value 0.29)

Table 3. DBDC regression results for the South Moravian sub-sample.

Variable	**DBDC Estimates**
Intercept	5.128*** (0.160)
Varieties	0.015* (0.008)
Scale	1.477 (0.091)
Weibull Shape	0.677 (0.041)

Number of obs: 463
Log-likelihood: -596.04

Note: *, **, and *** represent 10, 5 and 1% significance levels, respectively; standard errors in parentheses.

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 (360 million Kč, equivalent to about $14.6 million)[3]. 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 $370,000. Considering the maximum

[3] Pers. communication, V. Holubec; budget documentation available at http://genbank.vurv.cz/genetic/nar_prog_rostlin/Dokumenty/Zasady_GZ_2017.pdf.

number of crop varieties that might be newly conserved in our experiment (35), our estimate of the total welfare benefits would increase by about $13 million to a total of $81 million.

In addition to our preferred regression, which used the double-bounded dichotomous choice model and included protestors, we also ran several other regressions as a robustness check (Table 4). In two of these alternative model runs, we estimated the single-bounded dichotomous choice model, and also examined the impact of excluding protestors, respondents defined as those 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. The full results for these regressions can be found in the appendix.

Table 4. Single- vs. double-bounded dichotomous choice model, including or excluding protestors

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	223 Kč (9.96)
Double-bounded dichotomous choice, protestors excluded	236 Kč (9.98)

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.

In addition to these analyses, an extended model was estimated in which a number of covariate variables were added. Only five of these variables were found to be significant: personal income (in 1,000 Kč intervals); a gender dummy (with male=1); “Gardener” (a dummy variable coded as 1 if the respondent personally cultivates crops for his or her own consumption); “Agr. adaptation important” (a dummy variable coded as 1 if the respondent agreed that it is important that measures be taken to help Czech agriculture adapt to climate change); and “Heard of genebank” (a dummy variable coded as 1 if the respondent had heard of genebanks before). All were associated positively with WTP for crop diversity conservation, except the male dummy.

Table 5. DBDC regression results with socioeconomic variables

Variable	Czech sub-sample	S. Moravian sub-sample
Intercept	4.765*** (0.269)	4.238*** (0.383)
Quantity	0.005 (0.003)	0.011 (0.007)
Income missing	0.191 (0.303)	-0.003 (0.368)
Personal income	0.197*** (0.071)	0.054 (0.088)
High education	0.047 (0.15)	-0.274 (0.234)
Gardener	0.192* (0.1007)	0.326* (0.169)
Male	-0.220** (0.106)	0.106 (0.173)
Age	-0.007 (0.005)	-0.004 (0.008)
Retired	-0.018 (0.178)	-0.151 (0.286)
Student	0.002 (0.226)	0.538 (0.422)
Unemployed	0.030 (0.269)	-0.233 (0.381)
Childless	0.024 (0.134)	-0.084 (0.211)
Village	-0.003 (0.118)	0.048 (0.180)
Agricultural job	0.641 (0.480)	0.590 (0.514)
Farmers' market	0.148 (0.148)	0.241 (0.345)
Heard of genebank	0.334*** (0.104)	0.649*** (0.174)
Agr. adaptation important	0.434*** (0.101)	0.746*** (0.163)
Prague	0.025 (0.165)	
S. Moravia	0.054 (0.167)	
Scale	1.323 (0.053)	1.381 (0.085)
Weibull Shape	0.756 (0.030)	0.724 (0.045)
	Number of obs: 965 Log-likelihood: -1249.17	Number of obs: 463 Log-likelihood: -568.42

Note: *, **, and *** represent 10, 5 and 1% significance levels, respectively; standard errors in parentheses.

These results indicate that 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 had heard of genebanks, thought adaptation in the agriculture sector was important, or gardened) than general socioeconomic variables, though males were shown on average to be willing to contribute less towards crop conservation, while those with higher incomes were shown to be willing to contribute more. 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.

5. Discussion and policy implications

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. 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 (Hox & Snijkers 1995). 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 (Eurostat 2016). 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 (Tietenberg 2012). 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 took their budget constraint into account 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 likely to have not been overly affected by this source of bias. While stated preference methods have been criticized by some economists (Hausman 1993), 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" (Carson and Czajkowski 2012; Arrow *et al.* 1993), 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.

Policy implications

The main finding of this research is that Czechs are 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, given by Dr. Vojtech Holubec of the Crop Research Institute.[4] 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 model, with and without protestors included, and the 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

[4] And available in the following budget document: http://genbank.vurv.cz/genetic/nar_prog_rostlin/Dokumenty/Zasady_GZ_2017.pdf.

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 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

Model	Estimated aggregate WTP	Benefit-cost ratio
SBDC, protestors included	$42 million	2.8
SBDC, protestors excluded	$55 million	3.8
DBDC, protestors included	$68 million	4.6
DBDC, protestors excluded	$71 million	4.9

Note: 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.

6. Conclusion

By 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 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.

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 (Birol *et al.* 2006), or in developing countries in Africa, Asia and Latin America. In all cases, 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.

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Appendix A – Additional Tables

Table A1. Sub-samples and percentage of speeders

Sub-sample	mode	N (completed)	% of 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)	% of protestors	**N valid**
Czech Republic representative	**CAWI**	965	8.5%	**883**
S. Moravia representative	**CAWI**	463	9.3%	**420**

Table A3. SBDC regression results for the Czech representative population, protestors included

Variable	**Coefficient**
Intercept	0.410*** (0.142)
Varieties	0.005 (0.004)
Bid	-0.003*** (0.000)

Number of obs: 965
Log-likelihood: -640.018

Note: *, **, and *** represent 10, 5 and 1% significance levels, respectively; standard errors in parentheses.

Table A4. SBDC regression results for the Czech representative population, protestors excluded

Variable	Coefficient
Intercept	0.532*** (0.150)
Varieties	0.006 (0.005)
Bid	-0.003*** (0.000)

Number of obs: 883
Log-likelihood: -589.074

Note: *, **, and *** represent 10, 5 and 1% significance levels, respectively; standard errors in parentheses.

Table A5. DBDC regression results for the Czech representative sub-sample, protestors excluded

Variable	Coefficient
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: -1224.092

Note: *, **, and *** represent 10, 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?[5]

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.

[5] An English version of the text provided in Czech to survey respondents before the start of the contingent valuation questions.

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