Economic Valuation of Biodiversity: Measuring Willingness-to-Pay for Quinoa Conservation in Peru

Craig Scott (& Sarah Elmes)

Department of Economics
University of San Francisco
2130 Fulton St.
San Francisco, CA 94117

e-mail: *cscott@usfca.edu*

Last Update: December 2017

Abstract: Peru is facing increasing homogenization of traditional crops as a result of international market pressures. Destruction of the genetic resource base creates vulnerability to disease, climate, and pest shocks which threaten food security and the economic future of Peru's agricultural sector. This paper aims to determine whether informational priming on the non-market value of national identity is sufficient to change the willingness to pay for agro biodiversity programs among the Peruvian general population in both urban and rural areas. A choice set willingness to pay experiment combined with choice rankings and randomized priming measures how much individuals are willing to contribute to conservation programs, whether national identity is a factor which affects the amount they are willing to pay, and which factors of conservation they prefer. By offering an opportunity to donate a part of participation payments to a conservation group, the experiment also examines whether hypothetical stated preference measures of the non-use value of an environmental public good are incentive compatible.

The author wishes to thank Adam Drucker of Bioversity International, Alex Orsola-Vidal of CEGA, Elizabeth Katz of USF, and Willy Pradel of CIP for their logistical support during the field research phase. Thanks also go out to Bruce Wydick of USF for econometric model guidance, and do Sarah Elmes of USF for her contributions as an equal partner and co-author of all work and research so far conducted.

1. Introduction

Peru is one of the most important centers of crop biodiversity around the world. Historically, the country has been home to hundreds of varieties of staple crops such as potatoes and quinoa – which has exploded in popularity throughout the developed world as a, “super food”. Peruvian farmers have traditionally domesticated and harvested select varieties of crops that exhibit the greatest resilience to the environment in which they are grown. Some examples of environmental factors that influence breed selection include weather/climate, altitude, water delivery (for example, rain versus mist), and risks created by pests and disease.

In recent years, market pressures for homogeneity in produce have greatly reduced crop variation, leading to degradation of the underlying genetic diversity. This results in greater vulnerability of production systems to shocks. Biodiversity in staple crops is necessary for breeding programs which seek to improve yields, account for uncertainty in weather and disease conditions, enable adaptation to different conditions (for example, selecting varieties which can be grown in large fields at low altitudes using modern irrigation systems or hydroponics), and increasing durability for storage, transportation, and use in modern food products (Jacobsen and Mujica 2002).

Individual farmers often make decisions based on private costs and benefits, growing whichever varieties add the most value to their land. However, as the market pushes farmers towards crops of a single species (or other singular trait such as color or grain size), vulnerability to shocks on a system- wide scale increase. Maintaining a healthy genetic base is crucial for long term food source stability.

This study ultimately explores two fundamental questions:

First, can we measure the value of agrobiodiversity via willingness to pay for conservation programs? Specifically, these are initiatives run by the government or a non-profit non-governmental organization to promote the maintenance and production of traditional and/or heritage varieties of a crop. We use a consumer choice experiment which provides willingness to pay (WTP) values for both biodiversity programs as a whole along with specific conservation-related attributes.

Second, can we include information within the survey instrument that influences this value? Specifically, does information related to the non-market value of national identity have a measureable effect on willingness to pay for conservation?

Our findings will be used to orient overall conservation policy and support the design of cost-effective conservation initiatives for both our partner organization (Bioversity International), and any other bodies who seek to promote efforts to preserve genetic diversity.

2. Literature Review

In examining the current state of knowledge on the subject, we choose to study literature that highlights three different aspects of (agro) biodiversity. The first is whether biodiversity has economic value that needs to be conserved at all, whether that is reflected in the market, and whether individuals are willing to pay for it in any context. Second, we study willingness to pay more generally – how the value of natural resources is measured, and whether priming is an effective method of manipulating how much individuals are willing to pay. Third, we examine papers which contribute to the specific methodology of our research design – how choice sets can be used to measure willingness to pay, and how we can verify the results of hypothetical survey decisions.

Brock and Xepapadeas (2003) argue that biodiversity is traditionally praised without measureable merit. Rather than accepting it as something inherently good or virtuous, in any economic model biodiversity needs to create or enhance some kind of value. They create a simplified model in which the optimum steady state proportions of 2 crop varieties on a fixed plot of land can be calculated. The authors find that these optimizations are characterized by the existence (of lack of) property rights to the gene pool. Social optimums include crop diversity as a means of minimizing the value lost to continually evolving pests. Private optimums, however, generally result in mono-crops. There are three simple takeaways from this research: First, genetic diversity in crops reduces pest effectiveness, increasing overall yields. In this manner it works as an insurance mechanism, in which the risk to any one pest is spread among various species of a crop. Second, human work in the GMO sector is not a perfect substitute for naturally occurring diversity, as it incentivizes cultivation of fewer varieties. The authors argue artificial use of GMO looks good on paper, but it greatly increases vulnerability to pest shocks, as it only takes one unforeseen pest evolution to wipe out an entire mono-crop. Third, and most importantly, the social optimum levels of diversity depend on full property rights over the gene pool, suggesting that agro biodiversity is susceptible to the tragedy of the commons (Hardin 1968).

Pearce and Moran (1994) reinforce the notion of genetic diversity as a public good. Their work argues that natural resources have an economic value, and that their degradation to satisfy economic activities with lower values is evidence that, “[genetic] conservation generates economic values that are not captured in the marketplace” (122). The authors claim that this market failure is a result of the public goods nature of biodiversity, in which individual actors have little incentive to protect genetic variation.

Evenson and Santaniello (1998) explore the difficulties in identifying the contributions of any one particular local breed or variety of crop in improving the species as a whole, as the genetic traits are not formally traded in markets. This research reinforces the need for a diverse gene pool, as it is almost impossible to distinguish those breeds, which will make a difference in adapting to future shocks (which are inherently unpredictable).

The theory of Total Economic Value states that there is value beyond simple consumption or direct use most often accounted for in economic valuation of natural resources. All-encompassing values of any environmental asset must include both use (actual and option) and non-use (existence, altruistic, and bequest) values (OECD 2006). Non-use values can only be obtained through hypothetical stated preference techniques, which is what we use for this paper. Agro biodiversity falls primarily under existence value, which is the value of an asset that one does not directly consume (although one might consume quinoa, they do not consume the genetic pool). Therefore, agro biodiversity has a value, although it is not tangible and therefore not measureable through standard market means. One important note is that stated preference survey methods measure subjective values, not intrinsic ones. It’s therefore possible that the human value of genetic diversity is much smaller than it’s intrinsic value due to lack of information or perception.

Plottu and Plottu (2007) further argue that a multidimensional framework is needed to derive the value of any natural resource in order to be inclusive of both use and non-use values.

3. Hypotheses

Our main testable hypotheses are as follows:

H_0: Informational priming has no effect on willingness to pay for agrobiodiversity and conservation programs.

H_1: Information priming has an effect on willingness to pay for agrobiodiversity and conservation programs

4. Data

4.1. Population and Questionnaire

The population of interest is for our study is the general adult population of Peru. This population is chosen as the issues of crop vulnerability effect the entire country, and the scale of conservation programs also often require funding at a level only made possible by nationwide investment (Drucker 2001).

We conducted 200 surveys in the cities of Lima, Cusco, and Puno, split evenly between urban and rural districts (surveys in Lima were conducted in urban districts only, due both to the city's size and overwhelmingly urban population relative to Cusco and Puno). However, As of now, only the datasets for Puno and Lima have been sufficiently cleaned for use. Therefore, it should be noted that only two-thirds of the sample is represented in the data analysis.

The data collected from each individual includes the following:

- Awareness / experience with different varieties of quinoa.
- Prior history regarding donation behaviors (whether the subject has made prior donations, in what form, what amount, and to what kinds of causes).
- Basic demographic information (gender, age, occupation, income, education, household composition
- Socio-economic indicators (ownership of certain indicator assets such as a mobile phone or car, construction quality of residence, type of cooking fuel, access to clean water, electricity, internet, etc.).

Data related to the choice experiment portion of the survey is discussed under section 5 (The Model).

Subjects were chosen via convenience sampling, which does present a potential problem with uneven demographics. During the initial design of our research, we intended to track demographics as surveys were completed via a Google form, completed after each survey by our enumerators. Unfortunately, this proved to be too technically challenging for our enumerators. However, given the experimental design and randomized treatment, we don't anticipate any major issues arising from demographic imbalances (although it may impact the external validity of our findings)

4.2. Summary Statistics

The summary statistics are so far quite encouraging. Table 1 shows a breakdown of the sample by treatment group and city. The treatment groups are roughly even across both cities. This is to be expected since treatment group was randomized using systematic random sampling. Surveys were arranged in a repeating pattern by treatment prior to distribution to enumerators.

Table 2 provides the average values for some key demographic variables (gender, age, education level, and income level) by treatment group. To ensure there are no significant demographic differences between the treatment groups, a series of t-tests are run for each of the variables in Table 2 for each unique pair of treatments. The t-values from these tests are displayed in Table 3. The only difference of note is that of age between the control group and the treatment group primed with information regarding national identity. The difference is significant at the 5% level, however we are currently unable to make an argument for this difference having any meaningful effect on our findings.

5. Model

Our survey utilizes a consumer choice experiment in which each participant is presented with a series of 8 choice cards. Each card lists 3 hypothetical conservation programs, which are represented as a bundle of values for five different attributes. One of the programs on every card is the, “Status Quo” – a program which contains the worst possible value for each attribute. The attributes and their possible values are as follows:

- Preservation of the Andean Landscape (Increase / Maintain / Decrease)
- Risk of Production Loss (Low / Medium / High)
- # of Quinoa Species Existing in 50 Years (10% / 50% / 90%)
- Maintenance of Cultural Traditions (Yes / No)
- Cost of Hypothetical Donation (0 / 2 / 5 / 10 / 25 / 50 / 100)

Participants select a program from each card, the attribute values for which are generated using a random orthogonal design. There are 64 total choice cards, organized into blocks of 4 which are assigned to the surveys at random.

We currently model each program as an independent binary choice. This results in 24 (8 cards x 3 programs per) observations per individual, containing the program attribute variables, a binary choice variable, and all demographic and socio-economic information.

We utilize a conditional logit model to derive willingness to pay from the attribute values of the programs selected (or not selected) by the subjects in our sample. Once these values have been calculated, a two-sided t-test is used to determine whether the average values for willingness to pay are different with statistical significance between those who received the priming treatment and those who did not.

6. Results

The first model used is a simple conditional logit. The conditional logit model works similarly to a fixed-effects logit model for panel data. We include grouping by subject id in order to control for all subject-level characteristics. This ensures that choices are analyzed based solely upon the attributes and their values.

Using the conditional logit coefficients, WTP is calculated by dividing the attribute coefficient by the cost coefficient (contribution made by Zander). An alternative version of the model devised by the authors under the advice of USF's Professor Bruce Wydick is similar, but includes an interacted variable for each attribute and cost, which is added to the denominator. The basic form for this calculation is shown in Figure 1 below.

Figure 1.

$$WTP = \frac{\beta_1}{\beta_2 + \beta_3}$$

$\beta_1 =$ attribute coefficient

$\beta_2 =$ cost coefficient

$\beta_3 =$ attribute*cost interacted coefficient

Initial results from the basic conditional logit output are included in column 1 of Table 4. WTP values from using these coefficients are included in Table 5. It should be noted that the WTP values are strikingly high given the unit of measurement for the cost attribute (Peruvian Soles). The most expensive conservation plans offered cost 100 soles, which were chosen by relatively few subjects. In fact, the average cost of a program that was chosen was ~20 soles. I am therefore dubious that combined WTP values of >100 for all attributes is totally accurate. These irregular findings are robust to a number of tweaks to the conditional logit regression used. Looking at table 4, column 2 adds interacted variables as mentioned in the Wydick model mentioned above. Columns 3 and 4 repeat the same regression as 1 and 2, but with attribute levels recoded using effects coding (e.g. -1,0,1 as opposed to 0,1,2). Columns with effects coding are denoted with "fx" below the variable.

However, coefficients are similar across all variants of the conditional logit model used – all resulting in high WTP values. I suspect that this results from the very low-cost coefficient, which drives the overall WTP higher as the denominator gets smaller. This is something for further consideration as research continues. Using interacted variables drives the price coefficient down to almost 0, resulting in even higher WTP values.

Initial examination of the basic conditional logit coefficients show that all attributes had a significant effect, and that magnitudes are going in the correct and expected directions (increasing attribute levels should make subjects more likely to choose that program, given the assumption that all subjects prefer more conservation all else equal). While we can't get an idea of how the marginal probability of choosing a program changes with the attribute value from these coefficients alone (more on this later), we can get an idea of which attributes played the greatest role in influencing subjects behavior. Culture had the highest values, suggesting that increases in culture impact a programs attractiveness the most (although this could be because culture was the only binary variable…).

Next we take a look at the marginal effects coefficients for the basic conditional logit model (Zander). These are found in Table 6. The marginal effect coefficients provide a more intuitive understanding of how changes in attribute level impact individual preferences for a program. An increase in the attribute by 1 point (or level) increases a subject's likelihood of choosing that particular program by the coefficient of that attribute's marginal effect. These results are identical using both regular and effects coding for variables, as the marginal effect measures the effect of an increase in the attribute, not necessarily the value itself.

Now that we have some WTP values (even if their authenticity is in question for now), we can compare them across the treatment groups to try and see what effect our priming had. Table 7 and Figure 2 both provide a breakdown of attribute-specific WTP values by treatment group.

A major challenge for us at the moment is the inability to compare the treatment group means for significance, as there is only one WTP number given per group. This is an area that will require continued research throughout the intersession, as well as follow up with our partners at Bioversity. However we can perform a rough robustness check by looking at the average cost of programs chosen by each treatment group. Table 8 provides the average costs for chosen programs across each group. Performing restricted regressions of cost on treatment (restricted such that there are only ever 2 values for treatment per regression, as we cannot do a t-test between 3 groups) shows a statistically significant difference between cost for the control and national identity priming groups, but not between control and food security groups. At this point, we can tentatively assert that the national identity priming had an effect on subject preferences. This supports the finding that the WTP value for culture was highest in the national identity group, as that priming was created with that particular attribute specifically in mind.

7. Conclusions, recommendations for programs & policy, further work 1 page

In summary, we find that we can decompose individual preferences for conservation programs across multiple different attributes. Furthermore, informational priming on national identity can increase both overall WTP values and specific attribute values. This carries some very important policy implications for the marketing of environmental programs. We've shown that environmentalism isn't immune to the need for strong, well-targeted marketing. A possibly study might explore whether the boost in WTP values is short-lived, or whether it causes any long-term behavior shifts.

There may, however, be limits to the external validity of this work. Further work would be required to unpack exactly which aspects of priming motivate changes in value. Our study used differing techniques for each (historical information for national identity vs. household budget questions for food security). Additionally, the national identity priming may have simply resonated with either it's paired attribute, or the sample that was included in the study.

Additionally, there's still a great deal of work to be done in understanding how exactly to interpret the conditional logit results, and their corresponding WTP values. Particularly troubling is the fact that including interacted variables drives the cost attribute down to 0. During the survey pilot period, we found that cost was actually a high motivating factor for many.

Finally, there can be issues with hypothetical bias, in which subjects are unable to accurately choose programs they would actually pay for if given the chance. Our budget unfortunately prevented a check for hypothetical bias across the entire sample. Nevertheless, even if the WTP values are inaccurate, we believe they are fairly robust as ordinal markers. More simply put – we're still not 100% sure what exactly people are willing to pay, but we're getting closer to figuring out how to move that number around.

Appendix:

Table 1. Number of Subjects by Treatment and Location			
	Puno	**Lima**	**Total**
Control	64	67	131
Nat. Identity Priming	67	66	133
Food Sec. Priming	69	67	136
Total	200	200	400

Table 2. Average Demographic Values by Treatment				
	Gender	**Age**	**Education**	**Income**
Control	0.49	42.45	2.15	1.64
Nat. Identity Priming	0.51	38.73	2.10	1.50
Food Sec. Priming	0.48	40.66	2.14	1.41
Total Sample	0.49	40.61	2.13	1.51

Table 3. Testing for Significant Demographic Differences by Treatment			
	Control vs. National Identity	**Control vs. Food Security**	**National Identity vs. Food Security**
Gender	t = -0.3680	t = 0.1728	t = 0.5054
Age	t = 2.2402	t = 1.0394	t = -1.1888
Education	t = 0.4953	t = 0.1083	t = -0.3570
Income	t = 1.2164	t = 1.7834	t = 0.6373

Table 4. Conditional Logit Regression Coefficients

VARIABLES	(1) choose	(2) choose	(3) choose	(4) choose
	basic	interacted	fx basic	fx interacted
landscape	0.270***	0.282***	0.270***	0.282***
	(0.0308)	(0.0402)	(0.0308)	(0.0402)
production	0.401***	0.420***	0.401***	0.420***
	(0.0297)	(0.0372)	(0.0297)	(0.0372)
variety	0.0127***	0.0132***	0.510***	0.527***
	(0.000742)	(0.000931)	(0.0297)	(0.0372)
culture	0.907***	1.043***	0.454***	0.521***
	(0.0501)	(0.0634)	(0.0250)	(0.0317)
cost	-0.0110***	-0.000404	-0.0110***	-0.000404
	(0.000861)	(0.00194)	(0.000861)	(0.00194)
landscape*cost		-0.00175		-0.00175
		(0.00108)		(0.00108)
production*cost		-0.00191		-0.00191
		(0.00126)		(0.00126)
variety*cost		-5.79e-05**		-5.79e-05**
		(2.34e-05)		(2.34e-05)
culture*cost		-0.00694***		-0.00694***
		(0.00173)		(0.00173)
Observations	9,600	9,600	9,600	9,600

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Table 5. Willingness to Pay Value for Each Attribute	
Attribute	**Willingness-to-Pay**
Landscape	24.61
Production	36.61
Variety	1.16
Culture	82.83

Table 6. Marginal Effects of Basic Condtional Logit

VARIABLES	(1) choose	(2) margins	(3) choose	(4) margins
			fx	fx
landscape	0.270***	0.0497***	0.270***	0.0497***
	(0.0308)	(0.00555)	(0.0308)	(0.00555)
production	0.401***	0.0739***	0.401***	0.0739***
	(0.0297)	(0.00526)	(0.0297)	(0.00526)
variety	0.0127***	0.00235***	0.0127***	0.00235***
	(0.000742)	(0.000124)	(0.000742)	(0.000124)
culture	0.907***	0.167***	0.907***	0.167***
	(0.0501)	(0.00884)	(0.0501)	(0.00884)
		-		-
cost	-0.0110***	0.00202***	-0.0110***	0.00202***
	(0.000861)	(0.000161)	(0.000861)	(0.000161)
Observations	9,600	9,600	9,600	9,600

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Table 7. WTP Values by Treatment and Attribute		
Control	Landscape	21.08
	Production	32.29
	Variety	1.12
	Culture	72.16
National Identity Priming	Landscape	32.67
	Production	40.39
	Variety	1.26
	Culture	117.21
Food Security Priming	Landscape	21.97
	Production	36.96
	Variety	1.12
	Culture	67.05

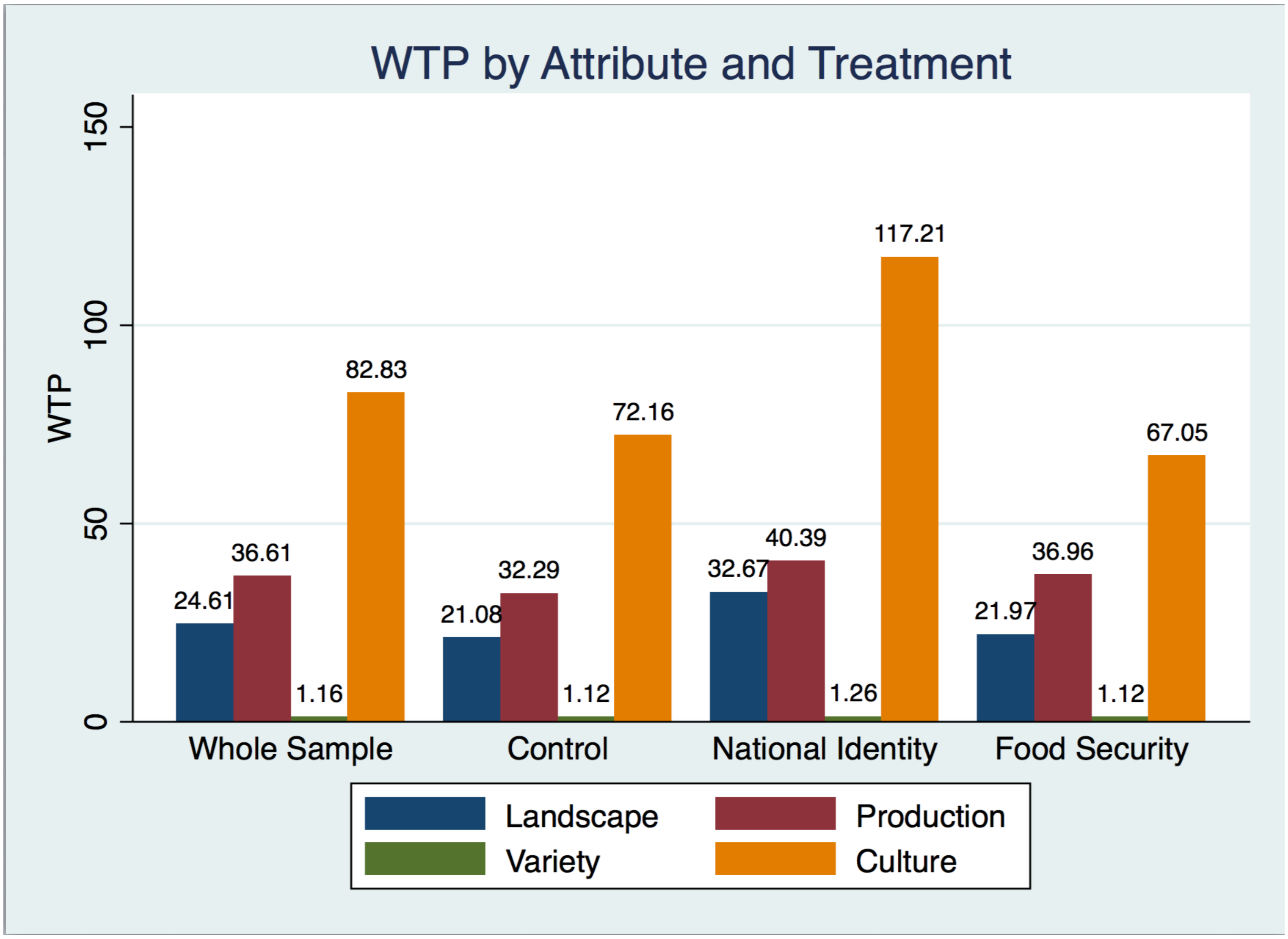

Figure 2. Graph of WTP Values by Attribute and Treatment

Table 8. Average Cost of Chosen Programs by Treatment Group	
Treatment Group	**Mean Cost of Chosen Programs**
Control	17.044
National Identity	21.68
Food Security	18.23
Total	19.98