Chapter 3

VALUING PUBLIC GOODS IN A RISKY WORLD: AN EXPERIMENT*

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1 INTRODUCTION

Most studies aimed at determining the willingness to pay for public goods consider a single change in the provision of such goods, for example, from a low to a high level of supply. It is perhaps not too surprising that such studies generally report a positive and realistic average willingness to pay; see e.g. Schulze et al (1981). After all, one expects people to be willing to pay out of their limited incomes for something that contributes to utility. Therefore, further attempts to validate willingness to pay measures seem to require that respondents are asked to express their willingness to pay for more than a single change in the provision of the considered public good.

In addition, many public sector programmes involve various elements of uncertainty. For example, the outcome of a particular programme may be uncertain. One of the current frontiers in valuation studies is associated with modeling and measuring benefits in such cases. In particular, the recent discussion between Mitchell and Carson (1985) and Greenley et al (1985) highlights that the implications of uncertainty with regards to the formulation and interpretation of willingness to pay questions remain unclear; see the aforementioned authors and also Brookshire et al (1983) for details. Therefore, it seems to be an important task to examine the possibilities and the limitations of questionnaire techniques in determining the willingness to pay for public goods in a risky world.

The present paper reports some preliminary results from an attempt to shed some light on the possibility of estimating money measures in a risky world. As a by-product the paper also reports some results on the consistency of willingness to pay measures when respondents are asked to express their willingness to pay for more than a single change in the provision of a public good. The study is based on a questionnaire completed by 122 Swedes[1], who were told

* I would like to thank the participants in a seminar at the University of Stockholm and two referees for their helpful and stimulating comments on an earlier version of this paper.

[1] The questionnaire was mailed to a random sample of 200 Swedes, i.e. 61 per cent completed the questionnaire. Just one bid was recognized as a protest bid. This bid by a male respondent (on the CV_A–question to be defined below) has been deleted; out of the remaining bids there is one bid on SEK 20 000 (≈ $3 000) while the rest of the bids fall short of SEK 8 100. The reader should also note that in this paper we are not interested in the absolute level of the willingness to pay for a commodity but in the ranking of different measures. The ranking is the same whether or not the two extreme bids mentioned above are included or excluded.

that there are about 300 endangered species (animals, birds, and flowers) living in Swedish forests. The respondents were asked of their willingness to pay for four different programmes which would save some or all of the species. In particular, the outcome of one of the programmes was uncertain; it would save all species with a probability of one-half and every second species with a probability of one-half. The remaining programmes would save 50 per cent, 75 per cent, and 100 per cent of the species, respectively.

The design of the questionnaire enables us to test several hypotheses. Firstly, using attitude questions, we can examine if and why respondents attribute an existence value to endangered species. Secondly, the data set can be used to calculate five different willingness to pay measures. Economic theory is used to generate hypotheses concerning the relative magnitudes of these money measures, and the hypotheses are tested on the empirical material.

The paper is structured in the following way. Section 2 presents various reasons for attributing an existence value to a species, and reports some results from the questionnaire. In Section 3, a set of hypotheses regarding the relative sizes of different money measures is derived, while Section 4 reports an attempt to test these hypotheses. Section 5 contains some concluding remarks. The paper ends with an appendix containing some of the derivations needed for establishing the hypotheses presented in Section 3.

2 THE MODEL

A typical feature of many environmental resources is that they provide many different values. Following Boyle and Bishop (1985) one may distinguish between four more or less distinct values. First of all, there are consumptive use values such as fishing and hunting. Secondly, some resources provide non-consumptive use values. For example, some people enjoy bird watching, while others gain satisfaction from viewing wildlife. Thirdly, a resource may also provide services indirectly through books, movie pictures, television programmes, and so on. Finally, people may derive satisfaction from the pure fact that a habitat or species exists.

The present study is concerned with 300 endangered species. One would expect to find people who attribute different values to the preservation of the considered species. This is confirmed by the results of the questionnaire. For example, more than 50 per cent of the respondents claim that they themselves would benefit from the preservation of endangered species, possibly because this requires a shift to soft cutting technologies. In Sweden it is widely believed that today's forestry is performed in such a way that outdoor recreation is adversely affected.

In this section we will concentrate on existence values. For this reason, the following simple specification of the indirect utility function is employed:

$$V = V(p, z, y) \tag{1}$$

where p is a vector of prices of private goods, z is a public good, and y is fixed annual income. For reasons which will become apparent in the next section, the utility function is assumed to be cardinal.

In equation (1), z is interpreted as the number of species saved. It is assumed that $\partial V/\partial z \geq 0$, i.e. the individual's welfare is a non-decreasing function of the number of species saved. (Alternatively, z is interpreted as a 1×300 vector with $\partial V/\partial z_k \geq 0$ for $k = 1, ..., 300$.) An individual may derive satisfaction from a public good such as z on the narrow grounds of self-interest, i.e. through use values and indirect services[2]. The individual may also derive satisfaction from the preservation of endangered species, i.e. a larger z, per se, irrespective of whether he himself has any narrow advantage from this. In general, this kind of an existence value is motivated by altruistic behaviour. Boyle and Bishop (1985, p. 13), following Bishop and Heberlein (1984), suggest the following five altruistic motives for existence values.

(i) "*Bequest motives.* As Krutilla (1967) argued many years ago, it would appear quite rational to will an endowment of natural amenities as well as private goods and money to one's heirs. The fact that future generations are so often mentioned in debates over natural resources is one indication that their well-being, including their endowments of natural resources, is taken seriously by some present members of society.

(ii) *Benevolence toward relatives and friends.* Giving gifts to friends and relatives may be even more common than making bequests of them. Why should such goals not extend to the availability of natural resources?

(iii) *Sympathy for people and animals.* Even if one does not plan to personally enjoy a resource or do so vicariously through friends and relatives, he or she may still feel sympathy for people adversely affected by environmental deterioration and want to help them. Particularly for living creatures, sympathy may extend beyond humans. The same emotions that lead us to nurse a baby or stop to aid a run-over cat or dog may well induce us to pay something to maintain animal populations and ecosystems.

(iv) *Environmental linkages.* A better term probably exists here. What we are driving at is the belief that while specific environmental damage such as acidification of Adirondack lakes does not affect one directly, it is symptomatic of more widespread forces that must be stopped before resources of direct importance are also affected. To some extent this may reflect a simple "you've-got-to-stop'em-somewhere" philosophy. It may also reflect the view that if "we" support "them" in maintaining the environment, "they" will support us.

(v) *Environmental responsibility.* The opinion is often expressed that those who damage the environment should pay for mitigating or avoiding future damage. In the acid rain case, there may be a prevalent feeling that if "my" use of electricity is causing damage to ecosystems elsewhere, then "I" should pick up part of the costs reducing the damage."

In the present study, the respondents were asked if and why they themselves would gain from a programme that contributes to the preservation of the considered endangered species.

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[2] A change in z may affect some prices p, possibly including travel costs to recreation sites, and hence demand for these goods and services. However, in order to be able to derive some simple and useful results prices are held constant throughout, implying that we overlook changes in use values due to changes in prices. See Johansson (1987) and Smith (1987) for models including such effects.

About 60 per cent claimed that the programme contributes to their own welfare because it will give others an opportunity to enjoy the species. Referring back to Boyle and Bishop's classification, motives (i) and (ii) come to mind. Moreover, 75 per cent claimed that they would benefit from the programme because in their opinion every living species has a right to exist, a motive which resembles Boyle and Bishop's motive (iii). Finally, 45 per cent of the respondents mentioned both of the reasons discussed above. These empirical results lend some support to the hypothesis that many people attach a well-defined existence value to endangered species. Some further evidence is reported in Section 4 below.

3 WILLINGNESS TO PAY MEASURES

The respondents were told that about 300 endangered species – animals, birds, and flowers – are living in Swedish forests. If no measures are taken, e.g. a ban of forestry in some areas and the introduction of soft cutting technologies in other areas, all the considered species may become extinct. Therefore, the respondent was asked to make (once and for all) contributions towards programmes that would save some or all of the species. Four different programmes that would save some or all of the species were suggested. First of all, the respondent was asked about his willingness to pay for a programme – denoted Programme C below – which would save 50 per cent of the species. The respondent was then asked to contribute to programmes – Programme B and Programme A – that would save 75 per cent and 100 per cent of the species, respectively. Finally, the respondent was asked to pay for a programme – Programme D – designed in such a way that the probability is 0.5 that the programme saves all species and 0.5 that it saves 50 per cent of the species.

In the case of Programmes A to C, the willingness to pay measure follows from:

$$V(p, z^j, y - CV_j) = E_0[V(p, z_0^i, y)] = \sum_{i=1}^{n} \pi_0^i V(p, z_0^i, y) = V_0 \tag{2}$$

where CV_j is the compensating variation, i.e. the maximum (once and for all) payment the respondent is willing to make to secure the change, j = A, B, C, a subscript 0 refers to the initial or no-programme case, E_0 is the expectations operator, π_0^i is the probability that z_0^i species survive in the no-programme case, and V_0 is the expected level of utility attained in the no-programme case. The reason for taking expectations in the no-programme case is that the respondents were told that all species may (but need not) become extinct. Therefore, the respondent is assumed to use his own subjective probability distribution in order to calculate the expected utility of the no-programme case. By assumption, no such uncertainty surrounds the final, i.e. with-programme, situation.

If utility is strictly increasing in z (and the household is not satiated), it is trivially true that:

Proposition 1 $\quad CV_A > CV_B > CV_C.$

Recall that Programme A saves all species, Programme B saves 75 per cent and Programme C saves 50 per cent of the species. The set of strict inequalities in Proposition 1 constitutes the first hypothesis to be tested in Section 4.

Turning next to Programme D, the respondent faces uncertainty in both the initial and final situations. This is because the respondents were asked to contribute to a programme which saves all the species with a probability of one-half and saves every second species with a probability of one-half. The resulting money measure is called the ex ante compensating variation:

$$E[V(p, z^i, y - AP)] = E_0[V(p, z_0^i, y)] = V_0 \tag{3}$$

where AP is the ex ante compensating variation, E is the expectations operator associated with the final (programme) situation, $z^i = 300$ with a probability of one-half and $z^i = 150$ with a probability of one-half. Thus, AP is a uniform ex ante or state-independent (once and for all) payment such that the expected utility with the programme is equal to the expected utility without the programme.

One purpose of the study was to examine whether respondents actually calculate the AP measure or if they misinterpret the valuation question and report some other money measure. Fortunately, theory suggests certain relationships between the measures, which will give us a clue to this issue as well as to the question whether or not people have risk aversion. These relationships are summed up in Proposition 2.

Proposition 2 — If the utility function is increasing and strictly concave in z, then $CV_A > CV_B > AP > CV_C$.

In order to prove these claims, we use the fact that for a strictly concave utility function, Jensen's inequality asserts that:

$$V(p, \bar{z}, y) > E[V(p, z^i, y)] \tag{4}$$

where $\bar{z} = E(z^i)$, i.e. $\bar{z}$ is the expected value of z. In other words, if the consumer is risk-averse with respect to risk in z, he gains from having z stabilized at its mean value.

For Programme D, the expected value of z is 0.75. Now, recall that the respondent also was asked to pay for a programme (Programme B) which would save 75 per cent of the endangered species. Using the fact that all money measures considered refer to one and the same level of initial utility, (2)–(4) can be used to show that:

$$V(p, \bar{z}, y - AP) > E[V(p, z^i, y - AP)] = V_0 = V(p, \bar{z}, y - CV_B) \tag{5}$$

Since the left hand side expression exceeds the right hand side expression, it must be true that $CV_B > AP$. Thus, if the household is risk-averse, the willingness to pay for a programme which stabilizes z at $\bar{z}$ exceeds the willingness to pay for a "stochastic" programme with $\bar{z}$ as the expected outcome.

Obviously, it holds in addition that $CV_A > CV_B > AP > CV_C$, provided utility is increasing and strictly concave in z. This set of strict inequalities constitutes the second hypothesis to be tested in the next section. It enables us to provide a simple test of whether consumers have risk-aversion with respect to z. Moreover, it provides an indication of whether the respondents really calculated an AP measure.

However, it is possible that respondents actually calculated an expected consumer surplus measure. In the present context this measure is defined as:

$$E(CV) = 0.5CV_A + 0.5CV_C \tag{6}$$

i.e. E(CV) is a weighted average of the willingness to pay for the preservation of all species and the willingness to pay for a preservation of 50 per cent of the species. Proposition 3 relates the expected consumer surplus measure to the ex ante compensating variation AP and the willingness to pay CV_B for having z stabilized at z = 0.75.

<u>Proposition 3</u> If the household is risk-averse with respect to risk in z, then $AP \gtreqless E(CV)$. Moreover, if the expenditure function is strictly convex in z, then $CV_B > E(CV)$.

In general, $AP \neq E(CV)$. To prove this claim, the intermediate value theorem is applied to obtain:

$$V(p, z^i, y - CV_i) = V(p, z^i, y - AP) + V_y^i \cdot (AP - CV_i) \quad \forall i \tag{7}$$

where the derivative V_y^i is evaluated at some intermediate point y^i such that $y^i \in (y-AP, y-CV_i)$, i.e. $V_y^i = \partial V(p, z^i, y^i)/\partial y^i$. Taking expectations, rearranging terms, and invoking a familiar theorem from mathematical statistics, one obtains:

$$AP = E(V_y^i \cdot CV_i)/E(V_y^i) = E(CV) + COV(V_y^i, CV_i)/E(V_y^i) \tag{8}$$

where we have used the fact that the expectation of the product of two stochastic variables is equal to the product of their expected values plus their covariance, as is shown in e.g. Johansson (1987). Thus, $AP \neq E(CV)$, unless the covariance term is equal to zero, i.e. V_y^i is independent of z^i and income. Nevertheless, if the empirical data reveals a difference between the two measures and there are no systematic errors of measurement, it follows that the respondents did not calculate an expected consumer surplus measure. Therefore, the third hypothesis to be tested reads: AP $\neq$ E(CV).

To prove the second claim of Proposition 3, we use Jensen's inequality, assuming that the expenditure function is strictly convex in z. Then it must be the case that:

$$e(p, \bar{z}, V_0) < E\,[e(p, z^i, V_0)] \tag{9}$$

where $e(\cdot)$ is the expenditure function yielding the minimum expenditure necessary to realize the initial utility level when prices p and the public good z take on specified levels. According to (9), the level of expenditure necessary in order for the household to attain the prespecified utility level is lower if z is stabilized at $\bar{z}$ than if z is stochastic with expected value $\bar{z}$. Substitution of the following definitions:

$$CV_B = y - e(p, \bar{z}, V_0) \tag{10}$$

$$E(CV) = y - E[e(p, z^i, V_0)]$$

where $y = E_0[e(p, z_0^i, V_0^i)]$ and $V_0^i = V(p, z_0^i, y)$, into (9) establishes that $CV_B > E(CV)$. It should be mentioned that the inequality can also be produced by an indirect utility function that is strictly concave in z and income. This result is derived in the appendix at the end of the paper. In any case, $CV_B > E(CV)$ is the final hypothesis to be tested.

4 EMPIRICAL RESULTS

In this section, we will present a test of the hypotheses generated in Section 3. However, before turning to this test, another consistency test of the empirical material is reported.

In principle, the classification of values discussed in Section 2 can be used to design simple consistency tests of willingness to pay measures. For example, one sample of respondents can be asked to pay for use values while another sample is asked to pay for use values plus existence values (although it is far from trivial to provide stringent definitions of these concepts, as is shown in e.g. Bishop and Heberlein (1984), Johansson (1987), and Smith (1987)). Obviously, if agents behave in accordance with the predictions of economic theory, the average willingness to pay for use values plus existence values should be at least as large as the willingness to pay for use values (ceteris paribus).

Unfortunately, the sample of respondents considered here was only questioned regarding its total willingness to pay for various programmes aimed at the preservation of endangered species. For this reason, it is not possible to calculate use values and existence values for the individual respondent. However, Table 1 reports an attempt to isolate various values provided by Programme A (i.e. the preservation of all 300 endangered species). Each ("paying") respondent was asked to specify why he was willing to contribute to the programme. A few respondents, group 1 in the table, claimed that they would benefit only through use values and indirect services provided by the considered programme. A second small group of respondents, in addition to use values, attributed value to the fact that the programme would give others an opportunity to "consume" the saved species (benevolence in the table). The third group of respondents in Table 1 mentioned both of the aforementioned motives and also argued that every species has a right to exist (sympathy for animals in the table).

TABLE 1
Willingness to pay (WTP in SEK; a SEK ≈ $ 0.15 (U.S.)) for Programme A as a function of the stated motives for paying for the programme.

Motive	Average WTP
Use values (group 1)	300
Use values + benevolence (group 2)	500
Use values + benevolence + sympathy for animals (group 3)	2 300

Table 1 is based on an extremely low number of observations (4, 5, and 37 observations, respectively; many respondents state combinations of motives that do not fall in any of the "groups" defined in the table). The results are shown merely to indicate the possibility of using attitude questions to obtain rough estimates of different values/services provided by a natural resource. The ranking of the three willingness to pay measures in the table is the one predicted by economic theory, but further investigation involving much larger samples seems to be necessary before one can draw any definite conclusions about the appropriateness of the approach.

Turning to the willingness to pay for various programmes, some results based on 120 observations are reported in Table 2. A glance at the table shows that most of the results are consistent with the hypotheses generated in Section 3. Not surprisingly, the more species saved, the higher the willingness to pay, i.e. $CV_A > CV_B > CV_C$. The ex ante compensating variation AP, associated with a programme that saves all species with a probability of one-half and every second species with a probability of one-half, falls short of the willingness to pay CV_B for a programme which saves 75 per cent of the species. This result is consistent with a utility function which is strictly concave in the number of species saved z; i.e., people have risk-aversion with respect to changes in z. Also, AP is different from the expected compensating variation E(CV), the suggested interpretation being that the average respondent did not calculate his expected compensating variation when he was asked of his ex ante compensating variation.

TABLE 2

Average willingness to pay measures (SEK), where subscripts A, B, and C, refer to programmes which save 100 per cent, 75 per cent, and 50 per cent of the species, respectively.

	Average	Female	Male
CV_A	1 275	780	1 830
CV_B	775	670	895
CV_C	555	505	610
AP	655	560	770
E(CV)	915	645	1 220

All these results are consistent with the hypotheses generated in the previous section. However, according to Table 2, E(CV) exceeds CV_B, indicating an expenditure function that is strictly concave in z, and not strictly convex as expected. Moreover, it is seen that $E(CV) > CV_B > AP$. This set of inequalities is not easily explained[3]. For example, an indirect utility function which is globally strictly concave or convex in z and income cannot produce $E(CV) > CV_B > AP$, as is shown in the appendix at the end of the paper.

It seems reasonable to suspect that the unexpected result under consideration reflects a difference in risk attitudes between "poor" and "rich" people. However, the inequality $E(CV) > CV_B > AP$ is obtained for low income earners as well as for high income earners. The inequality is also "robust" with respect to the stated motives for "paying" for the preservation of endangered species[4]. On the other hand, there is a striking difference between men and women according to Table 2. For women one obtains the ranking $CV_B > E(CV) > AP$. This ranking suggests that women are risk-averse with respect to uncertainty in z; compare Propositions 2 and 3 in Section 3.

For male respondents, on the other hand, the Friedman-Savage (1948) type of diagram depicted in Figure 1 comes into mind. That is, the indirect utility function is concave in z for low z-levels and convex in z for sufficiently high z-levels. This kind of indirect utility function can, but need not necessarily, produce the inequality[5] $E(CV) > CV_B > AP$ reported in Table

[3] Note that it does not make sense to test if "mean" values are statistically different since there is just a single population, i.e. all respondents were asked to pay for each of the four different programmes considered.

[4] These results are not shown in Table 2 but can be obtained from the author on request.

[5] We refrain from presenting a formal proof that utility functions such as the one depicted in Figure 1 can generate $E(CV) > CV_B > AP$ since such a proof is space consuming and adds very little to the understanding of the problem under consideration.

2. The interpretation being that male respondents have risk aversion when many species are threatened, i.e. when z takes on low values, while they are more inclined to accept risks when z exceeds some critical level.

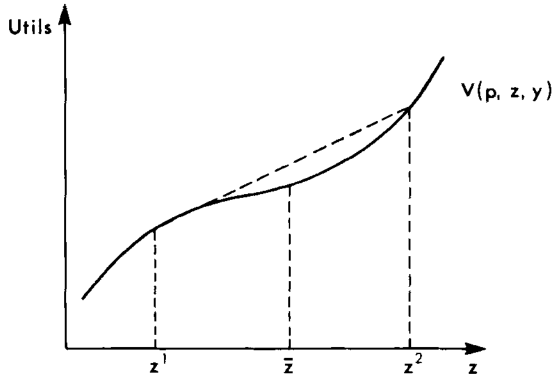

Figure 1. Diagram showing the relationship between utility and the number of species saved when the indirect utility function is concave in z for low z-levels and convex in z for sufficiently high z-levels.

Note: The broken line in Figure 1 shows that the consumer prefers a stochastic programme with expected outcome $\bar{z}$ to a non-stochastic programme with outcome $\bar{z}$. This is just to indicate that the ranking of various programmes is sensitive to the curvature properties of the utility function as well as the z-level.

In closing, it should be mentioned that the aforementioned difference between male and female respondents confirms earlier Swedish Gallup polls according to which Swedish women are more negative to environmental risks than Swedish men.

5 CONCLUDING REMARKS

This paper has reported preliminary results from an attempt to estimate willingness to pay measures for public goods in a risky world. Most of the results are consistent with the predictions generated by economic theory. For example, the willingness to pay is increasing in the number of saved species, which is the "public good" under consideration.

According to the data, there is an interesting difference in risk attitudes between male and female respondents. The data set suggests that female respondents have risk aversion with respect to the considered public good. Male respondents, on the other hand, seem to have risk aversion only if many species become extinct while they are more inclined to accept risky outcomes if just a few species are threatened.

Besides these explanations of the observed behavior, there is also the possibility that respondents are unable to calculate ex ante compensating variation measures and therefore report some other money measure when the situation involves uncertain outcomes. However, there is no strong case for the suspicion that the respondents calculated and reported an expected compensating variation measure instead of an ex ante compensating variation measure. Nevertheless, it is trivially true that even if a data set happens to confirm all of the hypotheses generated in Section 3 of the paper, this is no ultimate proof that the respondents did calculate one or the other money measure. In addition, the sample of respondents used in this study is very small, implying that some or all of the results may be due to random factors that a sufficiently large sample would cause to net out.

In any case, an implication of the research reported in this paper is that further attempts to validate the survey technique are in order. For example, such techniques can be used to let respondents identify additional points along what Graham (1981) calls the willingness-to-pay locus, i.e. all pairs of state dependent payments that leave the respondent's expected utility level unchanged. The two measures considered in this paper, the ex ante compensating variation and the expected compensating variation, represent just two out of possibly an infinite number of benefit measures (payment schemes) along the willingness-to-pay locus. A related issue that seems to deserve additional attention is what benefit measure is the appropriate one in situations involving uncertainty[6]. Obviously, for cost-benefit analysis of public sector programmes in a risky world to be possible and meaningful, it is necessary to have correct definitions of benefits and costs as well as reliable methods for their calculation.

APPENDIX: USING THE INDIRECT UTILITY FUNCTION TO DERIVE SOME RESULTS DISCUSSED IN SECTION 4

In order to show that $CV_B > E(CV)$ when the indirect utility function is (strictly) concave in (z, y), a variation of the mean value theorem is used to obtain:

$$V(p, z^i, y - CV_i) = V(p, \bar{z}, y - CV_B) + DV(p, \bar{z}, y - CV_B) \cdot x' + x \cdot D^2V(p, \tilde{z}, \tilde{y}) \cdot x'/2 \qquad (A.1)$$

where DV is the gradient, i.e. a vector of first partial derivatives evaluated at the point $(p, \bar{z}, y - CV_B)$, D^2V is a 2-by-2 matrix of second partial derivatives evaluated at a point $\tilde{z}, \tilde{y}$ such that $\tilde{z} \in (z^i, \bar{z})$ and $\tilde{y} \in (y - CV_i, y - CV_B)$, $x = (z^i - \bar{z}, CV_B - CV_i)$, and a prime denotes a transposed vector.

Taking expectations of (A.1), noting that $E[V(p, z^i, y - CV_i)] = V(p, \bar{z}, y - CV_B) = V_0$, and $\bar{z} = E(z^i)$, one obtains:

[6] A recent, although in the present author's eyes not completely convincing, discussion of this issue can be found in Cory and Saliba (1987). The basic reference is Graham (1981).

$$E(CV) - CV_B = E[x \cdot D^2V(p, \tilde{z}, \tilde{y}) \cdot x']/2 \cdot V_y \qquad (A.2)$$

where $V_y = \partial V(p, \bar{z}, y - CV_B)/\partial y$. The indirect utility function is strictly concave in z, y if $D^2V(\cdot)$ is negative definite. Then $x \cdot D^2V(\cdot) \cdot x' < 0$ implying that $E(CV) < CV_B$. See Turnovsky (1976) for a slight extension of this result.

Replacing CV_i in (A.1) by AP, it is straightforward to show that the considered indirect utility function produces $AP < CV_B$. Finally, if the indirect utility function is strictly convex in z, y, then $D^2V(\cdot)$ is positive definite in (A.2) implying that $CV_B < E(CV)$ and $CV_B < AP$.

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