Theoretical Foundations of Environmental Valuation: From Welfare Economics to Experimental Design Theory

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Abstract

Environmental valuation plays a major role in guiding policy decisions related to resource conservation, biodiversity protection, and sustainable development. Since most environmental goods and services are non-market in nature, their valuation requires a strong theoretical basis. This article synthesizes four major theoretical foundations that underpin contemporary non-market valuation methods. Welfare economics provides the framework for defining welfare changes through willingness to pay (WTP) and willingness to accept (WTA). Lancaster's characteristics theory of demand shifts the focus of consumer utility from goods to their underlying characteristics. Random utility theory (RUT), developed by Thurstone, Luce, and McFadden, establishes the probabilistic modelling of individual choice behaviour under uncertainty. Finally, experimental design theory addresses the reliability and statistical efficiency of valuation studies by ensuring optimal attribute selection and presentation. This paper addresses the role of these theoretical pillars to provide a coherent framework for understanding the methodological rigor behind environmental valuation. This synthesis contributes to strengthening the validity of valuation studies and offers practical guidance for designing robust empirical applications. The insights from this review are expected

ISSN: 2582 - 2594

to enhance the reliability of welfare estimates and support more informed environmental policy and decision-making.

Keywords: Environmental valuation; Welfare economics; Lancaster's characteristics theory; Random Utility Theory; Experimental design; Stated preference methods; Non-market valuation

Introduction

The application of various non-market valuation techniques in economic research requires a strong understanding of the underlying economic theory. This paper summarises the fundamental theoretical framework for modelling individual choice behaviour involving both marketed and non-marketed goods and services. The focus is primarily on the theoretical foundations of stated preference techniques, particularly Contingent Valuation (CV) and Discrete Choice Modelling (DCM). The study begins with examining how the principles of neoclassical welfare economics, and the Hicksian welfare measures, links to the economic valuation of non-marketable resources.

Empirical reviews have consistently demonstrated that CV has been widely applied for valuing public goods since the late 20th century (Mitchell & Carson, 1989). However, a bibliometric analysis of stated preference studies between 1987 and 2019 shows that while CV dominated the early decades, choice experiments gained increasing prominence after 2009 due to their ability to capture richer preference structures and accommodate multiple attribute trade-offs (Moreno-Sancho & Maldonado, 2020; Hoyos, 2010).

A significant extension to the neoclassical welfare framework came from Kevin Lancaster's (1966) characteristics approach which shifted the focus from goods themselves to their attributes. The framework was further advanced by Random Utility Theory (RUT), developed by Daniel McFadden (1974), which allows for the analysis of individual utility in discrete choice scenarios. RUT theorizes that individuals choose the alternative that maximizes their utility, incorporating both deterministic and stochastic components to account for observed and unobserved preferences. Finally, Experimental Design Theory provides the methodological basis for structuring stated preference studies. It ensures that the combinations of attributes and levels presented to respondents are statistically efficient and capable of capturing meaningful preference data.

Objective and Methodology

The primary objective of this paper is to examine the theoretical foundations underlying environmental valuation studies, with a particular focus on welfare economics, Lancaster's characteristics theory, random utility theory, and experimental design theory. The paper aims to demonstrate how they collectively inform non-market valuation techniques such as contingent valuation and choice experiments. The study also seeks to clarify the logical connections among these theories, and evaluate their implications for designing reliable and policy-relevant environmental valuation studies.

This study adopts a conceptual and theoretical review methodology that emphasizes the integration and synthesis of existing literature rather than empirical data analysis. Classical contributions in economics and econometrics are systematically examined alongside contemporary environmental valuation applications to establish a coherent narrative of theoretical evolution. The paper evaluates complementarities and limitations across these theories and demonstrates their practical relevance in guiding the design and interpretation of environmental valuation studies.

Theory of Consumer Behavior and Welfare Economics Principles

The traditional economic perspective on an individual's rational begins with the foundational theory of individual preferences and its relationship with welfare economics. The basic premise is that individuals are the best judges of their actions, and their behaviour under varying choice scenarios, provides insight into their preferences. However, individuals are not solely driven by material gains. Their welfare may be maximized for reasons that are "selfish, altruistic, loyal, spiteful, or masochistic" (Becker, 1992).

In neoclassical economic theory, individuals are assumed to be rational utility maximisers, ranking bundles of goods according to their preferences (Varian, 2014). These preferences satisfy nonsatiation and substitutability properties that give rise to well-defined demand functions. The theoretical framework can be formalised for three different contexts relevant to environmental and resource valuation: (i) purely marketed goods, (ii) marketed goods in the presence of non-market goods, and (iii) purely non-market goods. The derivation of ordinary and compensated demand functions in each case allows welfare changes to be measured via Hicksian welfare measures such as compensating and equivalent variation (Hicks, 1943; Freeman, Herriges, & Kling, 2014).

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Marshallian demand function is referred to as the ordinary or uncompensated demand function which depicts the relationship between price and quantity demanded under the assumption of utility maximization holding money income constant. Consumer surplus, the price that a consumer is actually willing to pay rather than go without an additional unit of good, quantifies the welfare a consumer derives from market participation.

The Hicksian demand function shows a consumer's demand for goods holding a constant utility level. Changes in prices of a good leads to a change in the quantity demanded through the substitution and income effects. Substitution effect measures a change in the consumption of a commodity after a price change, even after he was compensated enough to retain his original utility level. Income effect measures a change in the consumption of a commodity due to the real income effect of a price change, results from the gain (loss) of purchasing power.

The Hicksian compensated demand function is associated with the substitution effect alone, whereas the Marshallian ordinary demand function includes both income and substitution effects. When the share of income spent on a good is small, the Hicksian and Marshallian demand curves are nearly identical; when large, they diverge. They coincide only when the income effect is zero. The area under the compensated demand curve reflects total willingness to pay or accept, in such case, consumer surplus equal to compensating and equivalent variation.

3.1 Purely Marketed Goods: Ordinary and Compensated Demand

Let $X=[x_1,x_2,\dots,x_n]$ represent quantities of n marketed goods with prices $[P=p_1,p_2,\dots,p_n]$ and income M. The consumer's utility maximisation problem is:

$$\underbrace{Max}_{X}\, U(X) \;\; s.t. \sum_{i=1}^{n} p_i\, x_i \le M$$

Solving this problem yields the ordinary demand function:

$$x_i = x_i\,(P,M)$$

The consumer's expenditure minimisation problem is:

$$\underbrace{Min}_{X} \; \sum_{i=1}^{n} p_i\, x_i \;\; s.t. \;\; U(X) \ge \overline{U}$$

where $\overline{U}$ is a fixed utility level. This formulation yields the Hicksian Compensated demand function,

$$h_i = h_i(P,\overline{U})$$

Marshallian demand reflects income and substitution effects jointly, while

Hicksian demand holds utility constant and reflects only substitution effects (Deaton & Muellbauer, 1980).

3.2 Marketed Goods in the Presence of Non-Market Goods

In environmental valuation, non-market goods (e.g., air quality, scenic beauty) are often considered alongside marketed goods. Let Q = $[q_1, q_2, \ldots, q_n]$ denote quantities or quality levels of k non-market goods. The utility function becomes:

$$U = U(X,Q)$$

If Q exogenously determined, the Marshallian demand for marketed goods is:

$$x_i = x_i(P,M,Q)$$

In this case, welfare changes due to a variation in Q can be measured by the change in expenditure needed to achieve the same utility:

$$e(P,Q^1,U) - e(P,Q^0,U)$$

This mixed setting is the basis for stated preference valuation: changes in Q shift the demand for marketed goods, revealing the marginal willingness to pay for the non-market good (Lancaster, 1966; Freeman et al., 2014).

2.3 Purely Non-Market Goods

For purely non-market goods, there is no price vector P in the traditional sense. Instead, we imagine a hypothetical market where the non-market good Q could be traded. The consumer's maximisation problem becomes:

$$\underbrace{Max}_{Q}\, U(Q,Z) \;\; s.t. p_Z \le M$$

Where, Z is a composite market good and pQ is a hypothetical price for Q. The Marshallian demand for Q is then:

$$Q = \left(p_Q, p_Z, M\right)$$

Similarly, the compensated demand is:

$$H_Q = \left(p_Q, p_Z, \overline{U}\right)$$

In practice, these demand functions cannot be observed directly, but are inferred through stated preference methods such as CV and DCM, where respondents reveal hypothetical trade-offs between income and changes in Q (McFadden, 1974; Louviere, Hensher, & Swait, 2000).

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2.4 Maximization of Indirect Utility Functions – Compensating and Equivalent Welfare Measures

Natural resource use often involves trade-offs, as seen when rising tourist arrivals threaten biodiversity and ecosystem quality. A two-pronged strategy can help: limiting visitor numbers through regulated access and increasing entry fees to fund restoration efforts. Welfare economics provides compensating and equivalent variation measures to capture the monetary value of gains or losses in well-being resulting from such environmental changes.

Firstly, the Compensating welfare measure "C", is the amount that an individual is willing to pay to return to the original utility level after a policy change. It can be defined mathematically as

$$v(P^0,\ Q^o, y^o) = v(\ P^1, Q^1, y^1) - C$$

Here, the original utility serves as the reference, the "0" subscripts denote the initial conditions "1" subscripts denote the new conditions due to a policy change. If an individual is willing to give up welfare equal to "C", then there should be an improvement from initial conditions to new conditions so that he will remain in the original utility.

Secondly, the equivalent measure of welfare in which an individual required to pay an additional income with the initial conditions to obtain the same utility as after change. The Equivalent welfare measure, "E" can mathematically be defined as

$$v(\ P^0, Q^0, y^0 + E) = v(\ P^1, Q^1, y^1)$$

Equivalent measure recognized the final level of utility as the reference. Compensating variation is considered as appropriate when policy improves facilities without harming biodiversity. whereas, the Equivalent variation is found to be appropriate when policy restores or enhances environmental quality.

2.5 Variation in Welfare Measures for a Change in Price

A consumer may be better off or worse off depending on the direction of a change in price. We use the terms "Compensating Variation" (CV) and "Equivalent Variation" (EV) for compensating and equivalent welfare measures respectively. If the price decreases, the consumer would be better off than before and hence both measures would be positive. This can be represented as

$$CV = e\left(P_i^0, P_{-i}^0,\ Q^o, U^o\right) - e\left(P_i^1, P_{-i}^0,\ Q^1, U^o\right)$$

$$EV = e\left(P_i^0, P_{-i}^0,\ Q^o, U^1\right) - e\left(P_i^1, P_{-i}^0\ Q^0, U^1\right)$$

Here, P–*i* is the price vector left after removing Pi. Compensating and Equivalent variations can be measured as area under the Hicksian income compensated demand curve. We use integral calculus and Roy's identity for this purpose. We use s to represent pi along the path of integration.

$$CV = \int_{p_i^1}^{p_i^0} x_i^h \left(s, P_{-i}^0, U^0\right) ds$$

$$EV = \int_{p_i^1}^{p_i^0} x_i^h \left(s, P_{-i}^0, U^1\right) ds$$

2.6 A Change in Non-Market Goods and Welfare Measures

Changes in non-market goods can occur in many forms, such as an increase or decrease in forest cover, shifts in wildlife populations, or tree planting for commercial logging. The welfare effects of such changes are measured using the expenditure function. The compensating surplus (CS) and equivalent surplus (ES) are defined as:

$$CS = e(P^0,\ Q^o, U^o) - e(P^0,\ Q^1, U^o)$$

$$ES = e(P^0,\ Q^o, U^1) - e(P^0,\ Q^1, U^1)$$

The first derivative of the expenditure function with respect to non-market goods *qj* is the negative of its inverse Hicksian demand curve, which is also be equal to the shadow price of the non-market good *qj*. Using the fundamental theorem of calculus, the surplus measures can be expressed as integrals of shadow prices. Here Q^0_{-j} represents the price vector left after removing *qj* and s is the integration path of *qj*.

$$CS = \int_{q_j^0}^{q_j^1} p_i^v \left(P^0, s, Q_{-j}^0, U^0\right) ds$$

$$ES = \int_{q_j^0}^{q_j^1} p_j^v \left(P^0, s, Q_{-j}^0, U^1\right) ds$$

For normal non-market goods, the ES>CS for increases in the non-market

ISSN: 2582 - 2594

goods and the opposite is true for a decrease in non-market goods. This is because changes occur in quantity space for non-market goods, which are typically public and shared, with marginal valuations differing between individuals. In contrast, for market goods, changes occur in price space, where prices are public but quantities demanded vary.

2.7 Compensating and Equivalent Variations and Willingness to Pay

The concepts of Compensating and Equivalent Variation can be interpreted through Willingness to Pay (WTP) and Willingness to Accept (WTA), depending on the nature and direction of change (Hicks, 1939; Willig, 1976). WTP is typically associated with securing a desirable improvement, whereas WTA is linked to accepting compensation for an undesirable change (Hanemann, 1991). For environmental improvements, CV represents the monetary amount individuals are willing to pay to achieve the improvement, while EV denotes the amount they would require as compensation to forgo it. In the case of environmental degradation, CV reflects the amount individuals are willing to accept to tolerate the degradation, and EV represents the amount they are willing to pay to prevent it (Freeman, Herriges, & Kling, 2014).

Utility changes can be desirable, undesirable, or a combination of both. In the first two cases, WTP/WTA is applied directly. However, when changes include both beneficial and adverse elements, interpretation becomes more complex (Carson, Flores, & Hanemann, 1998). For a beneficial policy shift, CV is measured as WTP for the change and EV as WTA to forgo it; for detrimental policies, the relationship is reversed.

For aggregation, the Kaldor–Hicks compensation criterion remains a widely used decision rule (Kaldor, 1939; Hicks, 1939). This principle states that welfare improves if the gains to winners exceed the losses to losers, so that, in theory, winners could fully compensate losers. Redistribution could then occur to ensure no one is worse off. If the sum of the compensating measures is greater than zero, the proposed project passes the Kaldor test, and if the sum of equivalent measures is greater than zero, the proposed change passes the Hicks test. Satisfying either test shows a potential net welfare gain from the proposed change, although actual compensation may not be implemented in practice (Just, Hueth, & Schmitz, 2004).

Implicit Markets for Environmental Goods

Many environmental goods are non-market goods, meaning they are not directly bought or sold. But individual purchase it implicitly while demanding other goods. Choices related to leisure, recreation, housing, and other consumption often depend on environmental attributes such as air quality, water quality, or proximity to recreational areas (Rosen, 1974; Freeman, Herriges, & Kling, 2014). Thus, an individual's decisions to buy a market good also send some signals for his preferences for the non-market goods. For example, housing prices may reflect the value of clean air, and travel costs may reveal preferences for natural sites. In such cases, revealed preference methods—including the Hedonic Pricing Method and the Travel Cost Method—can be applied to infer the value of non-market goods from observed market behaviour (Palmquist, 2005; Haab & McConnell, 2002).

Introduction of weak complementarity condition allow us to value the changes in non-market goods through the changes in consumer surplus of for related market goods (Maler, 1974; Bockstael & McConnell, 1993). An increase in non-market good (q1) may increase the consumer surplus of the individual. In order to measure the monetary value of such change, we use the expenditure function and compensating surplus.

$$CS = e\left(P^0, q_1^0, Q_{-1}^0, U^o\right) - e\left(P^0, q_1^1, Q_{-1}^0, U^o\right)$$

If a price change occurs alongside the change in q1, the CS expression can be rearranged by adding and subtracting "zero terms" to separate the effects of price and quantity changes (Bockstael & McConnell, 1993):

$$CS = e\left(P^1, q_1^1, Q_{-1}^0, U^o\right) - e\left(P^0, q_1^1, Q_{-1}^0, U^o\right)$$

$$-e\left[\left(P^1, q_1^0, Q_{-1}^0, U^o\right) - e\left(P^0, q_1^0, Q_{-1}^0, U^o\right)\right]$$

$$+\, e\left(P^1, q_1^0, Q_{-1}^0, U^o\right) - e\left(P^1, q_1^1, Q_{-1}^0, U^o\right)$$

In this equation, the second and fourth terms are original terms and the rest four terms are "zero" terms arranged to get meaningful changes in the price levels. First line of the equation shows the value of price change at the new level of q1. Second line shows the negative of the value of the price change at the initial level of q_1 and the last portion represents the value of quantity change (q_1) at the new price level. This approach is mainly useful in Travel Cost Method applications, where changes in environmental quality alter both the implicit "price" of trips and the level of use (Parsons, 2003).

Weak complementarity is a situation where, the compensated demand for market good depends marginally positive on the level of q_1 and when the consumption of this market good becomes zero, the marginal effect on the demand for the change in q_1 is also becomes zero. One can effectively value the changes in non-market goods by measuring the compensating surplus from the weakly complementary good. Let us introduce a choke price p that chokes off the demand for this weakly complementary good. Suppose a change in price from the original price level to the choke price level, the compensating surplus becomes

$$CS = e\left(\hat{p}_1, P^0_{-1}, q^1_1, Q^0_{-1}, U^o\right) - e\left(p^0_1, P^0_{-1}, q^1_1, Q^0_{-1}, U^o\right)$$

$$-e\left[\left(\hat{p}_1, P^0_{-1}, q^0_1, Q^0_{-1}, U^o\right) - e\left(p^0_1, P^0_{-1}, q^0_1, Q^0_{-1}, U^o\right)\right]$$

$$+\, e\left(\hat{p}_1, P^0_{-1}, q^0_1, Q^0_{-1}, U^o\right) - e\left(\hat{p}^0_1, P^0_{-1}, q^1_1, Q^0_{-1}, U^o\right)$$

At the choke price, the demand for the weakly complementary good is zero, so the last term disappears, and the CS equals the change in total consumer surplus for the complementary good. This can also be expressed as the difference in the integrals of the Hicksian demand functions at q_1^1 and q_1^0 (Freeman et al., 2014).

$$CS = e\left(\hat{p}_1, P^0_{-1}, q^1_1, Q^0_{-1}, U^o\right) - e\left(p^0_1, P^0_{-1}, q^1_1, Q^0_{-1}, U^o\right)$$

$$-e\left[\left(\hat{p}_1, P^0_{-1}, q^0_1, Q^0_{-1}, U^o\right) - e\left(p^0_1, P^0_{-1}, q^0_1, Q^0_{-1}, U^o\right)\right]$$

$$+ \int_{\hat{p}_i^1}^{\hat{p}_i^0} x_1^h\left(s, P^0_{-1}, q^1_1, Q^0_{-1}, U^0\right) ds - \int_{\hat{p}_i^1}^{\hat{p}_i^0} x_1^h\left(s, P^0_{-1}, q^0_1, Q^0_{-1}, U^0\right) ds$$

This discussion can be extended to include multiple weakly complimentary goods. If demand for two market goods (x_1 & x_2) is zero, the marginal value of q_1 is also zero, and CS can be computed by summing the integrals over both goods. We use an additional price vector $P^0_{-1,-2}$ by removing the first and second elements of P^0.

$$CS = \int_{\hat{p}_1^0}^{\hat{p}_1} x_1^h\left(s, P_{-1}^0, q_1^1, Q_{-1}^0, U^0\right)ds - \int_{\hat{p}_1^0}^{\hat{p}_1} x_1^h\left(s, P_{-1}^0, q_1^0, Q_{-1}^0, U^0\right)ds$$

$$+ \int_{\hat{p}_2^0}^{\hat{p}_2} x_2^h\left(\hat{p}_1, s, P_{-1-2}^0, q_1^1, Q_{-1}^0, U^0\right)ds - \int_{\hat{p}_2^0}^{\hat{p}_2} x_2^h\left(\hat{p}_1, s, P_{-1-2}^0, q_1^0, Q_{-1}^0, U^0\right)ds)$$

The assumption of weak complementarity must be empirically tested before application. It requires the existence of a market price, not only the choke price, at which the marginal value is zero. If incorrectly assumed, valuation becomes biased: for increases in non-market goods, CS is underestimated, while for decreases, it is overestimated.

3.3 Lancaster's Theory of Characteristics Approach and its Extensions

The theoretical foundation of modern choice modelling lies in Lancaster's Characteristics Theory of Value (1966). Lancaster breaks away from the traditional theory which treats goods themselves are the direct source of utility. Instead, Lancaster argued that, utility derives from the characteristics or attributes of goods. A commodity is therefore viewed as a bundle of attributes, and consumption decisions are driven by the utility associated with these attributes rather than the goods per se.

Lancaster's framework rests on three key assumptions. First, each individual good or a collection of good represents a consumption activity, expressed as a linear relation between goods and activities

$$x=Ay$$

for j^{th} commodity we have,

$$x_j = \sum_k a_{jk}\, y_k$$

The coefficient ajk here depends upon the intrinsic property of the goods alone and are invariant across consumers.

Second, each activity produces a fixed vector of characteristics, also linearly related to the activity levels

$$z = By$$

Here, the goods are transformed into objective characteristics, z. Here B is a $R \times J$ matrix which transforms J goods (i.e., alternatives in a choice set) into R objective characteristics (i.e., attributes of alternatives). B is assumed to be

 ISSN: 2582 - 2594

objective since it is available to all consumers in equal terms. if zi is the amount of the i^{th} characteristic

$$z_i = \sum_k b_{ik}\, y_k$$

The objectivity assumption is maintained with regard to the bik coefficients, implying that all consumers face the same mapping from goods to characteristics.

Finally, individuals are assumed to maximize an ordinal utility function defined over characteristics, U(z), subject to the standard budget constraint. Hence, the consumer problem can be written as:

$$max\, U(z) \quad s.t\ px \le k, \quad z = By,\ x = Ay, \quad x, y, z \ge 0.$$

Here the max Uz is operating on the characteristic space and the budget constraint px≤k is operating on the goods space. The Uz can be represented as a composite utility function representing the vector of commodity characteristics.

$$U(z) = U(z_1, z_{2,}\ z_3 \ldots\ldots z_R)$$

The Lancaster model was widely welcomed because it provided a multidimensional link between economic models of consumer choice and the multi-attribute models of behavioral sciences. For instance, in an ecotourism setting, the choice of a destination is driven not by the site itself, but by its characteristics (recreational, ecological, cultural, or environmental). Lancastrian Approach is based on the assumptions that "goods are infinitely divisible, frequently purchased with a low unit value". This assumption is not hold true to many goods relevant to discrete-choice applications. However, Lancaster's original model had limitations: it ignored heterogeneity in perceptions of characteristics (e.g., shaped by advertising or word-of-mouth), and it did not account for variety-seeking behavior, both of which are important in many consumer contexts.

Rosen (1974) extended Lancaster's model to account for indivisible goods. In the standard framework, goods are assumed to be divisible and frequently purchased, which does not hold for many discrete-choice contexts. Rosen introduced a composite good alongside objective characteristics ($z_1, z_2, \ z_3 \ldots\ldots z_R$) and allowed for non-linear budget constraints.

$$max\, U(z_1, z_{2,}\ z_3 \ldots\ldots z_R) \quad s.t\ p\big(z_1, z_{2,}\ z_3 \ldots\ldots z_R\big) + d = M$$

Here M is consumer's money income, the price vector pz represents the price of one good yielding $z_1, z_2, z_3 \ldots\ldots z_R$ objective characteristics. If the goods are indivisible, then $p(z_1, z_2, z_3 \ldots \ldots z_R)$ need not be linear. Therefore, the budget constraint is also assumed to be nonlinear. "Rosen's model is more appropriate to discrete choice theoretic framework, although it continues to link utility directly to the objective characteristics of goods" (Louviere, et. all, 2000).

Further refinements were introduced by Louviere, Hensher, and Swait (2000). They argued that consumers derive utility not directly from characteristics, but from the services delivered by those characteristics.

$$U=U(s_1, s_2, s_3 \ldots \ldots s_K)$$

Since the level of services is partly subjective and often uncertain, they reformulated the model around expected services: "Utility is a function of the expectation of consuming a required level of service provided by characteristics which group to define a commodity" (Louviere, et. all, 2000).

$$U = U(se_1, se_2, se_3 \ldots \ldots se_K)$$

where se_K denotes the expected level of service from commodity k. An accurate measurement of attributes which define the expected level of services would remain a difficult task to solve. Recognizing that not all attributes are observable, the model was further generalized

$$U = U((se_o + se_{uo})_1, (se_o + se_{uo})_2, \ldots\ldots, (se_o + se_{u0})_K)$$

Where se_o and se_{uo} represents observed and unobserved component of commodity characteristics. The distribution of unobserved components (normal or extreme value etc.) forms the basis for probabilistic choice models.

3.4 Random Utility Theory

Random utility model (RUM) forms the basic theoretical framework behind Choice modelling and dichotomous choice CV method (Luce, 1959; McFadden, 1973). The development of RUT significantly contributed to the growth of econometric models for qualitative response variables. Thurstone (1927), in his seminal work "The Law of Comparative Judgment", made the first contributions to this theory, explicitly assuming that individuals act rationally in choosing alternatives but that these choices are influenced by unobservable random factors.

According to RUT, when an individual is presented with a set of alternatives, he may select the one which provides him the maximum utility. Consider a choice between two alternatives, i and j. The utility associated with each alternative can be decomposed into a systematic component i,j and a stochastic element $\varepsilon_i, \varepsilon_j$. The discriminant process associated with each alternative i, j represents

$$v_i = f(\alpha_i) + \varepsilon_i$$

$$v_j = f(\alpha_j) + \varepsilon_j$$

The functions $f(\alpha_i)$ and $f(\alpha_j)$f represents single valued functions of observable characteristics *αi* and *αi* participating in the *i, j,* pair, and the stochastic elements *εi* and *εj* follow a bivariate normal distribution. Let an individual *i* face *Mi* mutually exclusive alternatives forming a choice set *Ci*, where the perceived utility from alternative *j* is U_j^i . The individual chooses the alternative that maximizes utility.. A conditional indirect utility function for each individual influenced by observable attributes of both the alternatives and the individual can be shown as

$$U_j^i = U^i\left(X_j^i\right) + \varepsilon_j^i$$

Where, $U^i\left(X_j^i\right)$ is the deterministic component expressed as a vector of attributes X_j^i and ε_j^i is the stochastic term capturing unobserved influences. The term "latent utility" is often used because utility is indirectly derived. The systematic element in the latent utility construct includes all attributes used in the choice modelling as well as the covariates. The equation can be rewritten by including the individual characteristics in the form;

$$U_j^i = V^i(Z_j^i, S_i) + \varepsilon_j^i$$

The probability that individual *i* chooses alternative *j* from choice set C is the probability that the combined systematic and stochastic utility of j exceeds that of all other alternatives:

$$Prob(j|C = \text{Prob}\{V_j^i + \varepsilon_j^i > V_k^i + \varepsilon_k^i, \forall \in \text{C}\})$$

Assuming that the error terms are independently and identically Gumbel-distributed and distributed with scale parameter μ, the choice probability of choosing option j is given by:

$$Prob(j) = \frac{e^{\mu v_j}}{\sum_{k \in \text{C}} e^{\mu v_k}}$$

This formulation can be estimated using the usual Multinomial Logit model or Conditional Logit model. The scale parameter μ is inversely proportional to the standard deviation of the error distribution. As μ →∞, the model becomes deterministic. In order to keep the choices consistent with the Luce's axiom of Independence from Irrelevant Alternatives (Luce, 1959) μ is usually assumed to be equal to one, ensuring that the ratio of choice probabilities between two alternatives is unaffected by other options in the set. The RUM usually estimated using maximum likelihood procedures. The log-likelihood function for the estimation is given below

$$\log L = \sum_{i=1}^{N} \sum_{j=1}^{j} y_j^i \ log \left[\frac{e^{V_j^i}}{\sum_{k=1}^{J} e^{V_k^i}} \right]$$

Here $y_j i$=1 if respondent i chose alternative j and 0 otherwise. The WTP for each attribute can be measured using (Hanemann, 1984; Parsons and Kealy, 1992). If V_i^0 and V_i^1 denote utilities of the initial and improved states respectively, then

$$WTP =- \ \frac{b_c}{b_y}$$

The coefficient b_y is the coefficient of the cost attribute. For a linear utility specification, these formulae can be specified as the ratio of the marginal coefficient of any attribute (b_c) to the marginal utility of income represented by the coefficient of the cost attribute (b_y). These ratios represent the implicit prices of attributes.

$$WTP =- \ \frac{b_c}{b_y}$$

In referendum-style CV studies, the individual faces a binary choice between an environmental improvement (with payment) and the status quo (no payment). Denote the improved state by j and the status quo by k. The probability of choosing the improved scenario j is given by

$$Prob(j) = \frac{exp^{(V_j^i - V_k^i)}}{1 + e^{(V_j^i - V_k^i)}}$$

CE and CV models share the same random utility theory framework, the welfare estimates from each are directly comparable.

The standard Multinomial Logit and Conditional Logit models rely on the IID assumption of error terms. If this assumption is violated, more flexible models are required. Extensions of RUT relax the restrictive IIA assumption in the MNL Probit models assume normal error terms, whereas Logit models assume Gumbel-distributed errors (McFadden, 1974; Ben-Akiva and Lerman, 1985). Generalized Extreme Value assumptions give rise to Nested Logit (McFadden, 1981) or Ordered GEV models (Small, 1981). The IIA property can be formally tested using the Hausman–McFadden (1984) likelihood ratio procedure.

3.5 Experimental Design Theory

An important stage in the choice modelling approach is the specification of attributes and their levels, which form the basis of the alternatives presented to respondents. The success of any choice experiment depends on how well these attributes reflect the policy context and how they are combined into hypothetical alternatives. Both theoretical and empirical studies demonstrate that the reliability and validity of estimated models are highly sensitive to the experimental design employed (Hensher et al., 2005; Louviere et al., 2008; Bliemer and Rose, 2011). This becomes particularly crucial when sample sizes are limited, where inefficient designs may substantially inflate standard errors and compromise inference.

Experimental design theory addresses this challenge by providing statistical principles for the systematic allocation of attribute levels to alternatives in a manner that ensures efficiency and interpretability. As Hensher et al. (2005) note, an experiment may be defined as "the observation of the effect upon a response variable, given the manipulation of one or more explanatory variables." In the choice experiment context, these explanatory variables correspond to the attributes of the alternatives, while the response is the choice made by the respondent.

Over time, design approaches have evolved from orthogonal designs (ensuring independence between attributes) to D-efficient designs (minimizing the asymptotic variance of parameter estimates), and more recently to Bayesian designs, which incorporate prior information about parameters to further improve efficiency. These developments reflect the recognition that a mere random allocation of attribute levels rarely guarantees robust estimates of willingness to pay. Instead, experimental design theory provides a formal statistical basis for constructing designs that balance statistical efficiency, cognitive realism, and policy relevance.

3.6 Conclusion

Despite their theoretical robustness, both CV and DCM face methodological challenges. Reviews of CV applications highlight persistent concerns such as hypothetical bias, embedding effects, and scope insensitivity, which can compromise the validity of willingness-to-pay (WTP) estimates (McFadden & Train, 2017). A recent meta-analysis of CV studies further revealed that the income elasticity of WTP for ecosystem services is around 0.6, indicating that WTP grows less than proportionally with income—an insight with significant implications for adjusting valuation estimates across different income groups (Drupp, Turk, Groom, & Heckenhahn, 2023).

Reference

1. Bockstael, N. E., & McConnell, K. E. (1993). Public goods as characteristics of non-market commodities. The Economic Journal, 103(420), 1244–1257. https://doi.org/10.2307/2234249
2. Becker, G. S. (1992). Habits, addictions, and traditions. Kyklos, 45(3), 327–346. https://doi.org/10.1111/j.1467-6435.1992.tb02115.x
3. Ben-Akiva, M., & Lerman, S. R. (1985). Discrete choice analysis: Theory and application to travel demand. MIT Press. https://mitpress.mit.edu/9780262022170
4. Carson, R. T., Flores, N. E., & Hanemann, W. M. (1998). Sequencing and valuing public goods. Journal of Environmental Economics and Management, 36(3), 314–323. https://doi.org/10.1006/jeem.1998.1058
5. Deaton, A., & Muellbauer, J. (1980). Economics and consumer behavior. Cambridge University Press. https://doi.org/10.1017/CBO9780511805653
6. Drupp, M. A., Turk, Z., Groom, B., & Heckenhahn, M. (2023). Income elasticity of willingness to pay for environmental goods: A meta-analysis. Environmental and Resource Economics, 84(1), 67–97. https://doi.org/10.1007/s10640-023-00806-5
7. Freeman, A. M., Herriges, J. A., & Kling, C. L. (2014). The measurement of environmental and resource values: Theory and methods (3rd ed.). Routledge. https://doi.org/10.4324/9781315780917
8. Hanemann, W. M. (1984). Welfare evaluations in contingent valuation experiments with discrete responses. American Journal of Agricultural Economics, 66(3), 332–341. https://doi.org/10.2307/1240800
9. Hanemann, W. M. (1991). Willingness to pay and willingness to accept: How much can they differ? American Economic Review, 81(3), 635–647. https://www.jstor.org/stable/2006525
10. Haab, T. C., & McConnell, K. E. (2002). Valuing environmental and natural resources: The econometrics of non-market valuation. Edward Elgar. https://doi.org/10.4337/9781843765431
11. Hensher, D. A., Rose, J. M., & Greene, W. H. (2005). Applied choice analysis: A primer. Cambridge University Press. https://doi.org/10.1017/CBO9780511610356
12. Hicks, J. R. (1939). The foundations of welfare economics. Economic Journal, 49(196), 696–712. https://doi.org/10.2307/2225023
13. Hoyos, D. (2010). The state of the art of environmental valuation with discrete choice experiments. Ecological Economics, 69(8), 1595–1603. https://doi.org/10.1016/j.ecolecon.2010.04.011
14. Just, R. E., Hueth, D. L., & Schmitz, A. (2004). The welfare economics of public policy: A practical approach to project and policy evaluation. Edward Elgar. https://doi.org/10.4337/9781845424602
15. Kaldor, N. (1939). Welfare propositions of economics and interpersonal comparisons of utility. Economic Journal, 49(195), 549–552. https://doi.org/10.2307/2224835

ISSN: 2582 - 2594

16. Lancaster, K. J. (1966). A new approach to consumer theory. Journal of Political Economy, 74(2), 132–157. https://doi.org/10.1086/259131
17. Louviere, J. J., Hensher, D. A., & Swait, J. D. (2000). Stated choice methods: Analysis and applications. Cambridge University Press. https://doi.org/10.1017/CBO9780511753831
18. Luce, R. D. (1959). Individual choice behavior: A theoretical analysis. Wiley. https://doi.org/10.1037/14847-000
19. Mäler, K. G. (1974). Environmental economics: A theoretical inquiry. Johns Hopkins University Press. https://www.jstor.org/stable/10.2307/10.2307/10.2307
20. McFadden, D. (1974). Conditional logit analysis of qualitative choice behavior. In P. Zarembka (Ed.), Frontiers in econometrics (pp. 105–142). Academic Press. https://eml.berkeley.edu/reprints/mcfadden/zarembka.pdf
21. Mitchell, R. C., & Carson, R. T. (1989). Using surveys to value public goods: The contingent valuation method. Resources for the Future. https://doi.org/10.4324/9781315060569
22. Moreno-Sancho, D., & Maldonado, J. H. (2020). Trends and gaps in stated preference valuation of ecosystem services: A bibliometric analysis (1987–2019). Ecosystem Services, 46, 101213. https://doi.org/10.1016/j.ecoser.2020.101213
23. Palmquist, R. B. (2005). Property value models. In K. G. Mäler & J. R. Vincent (Eds.), Handbook of Environmental Economics (Vol. 2, pp. 763–819). Elsevier. https://doi.org/10.1016/S1574-0099(05)02016-2
24. Rosen, S. (1974). Hedonic prices and implicit markets: Product differentiation in pure competition. Journal of Political Economy, 82(1), 34–55. https://doi.org/10.1086/260169
25. Small, K. A. (1981). Estimating multinomial logit models from cross-sectional data. American Economic Review, 71(4), 461–471. https://www.jstor.org/stable/1806181
26. Thurstone, L. L. (1927). A law of comparative judgment. Psychological Review, 34(4), 273–286. https://doi.org/10.1037/h0070288
27. Varian, H. R. (2014). Intermediate microeconomics: A modern approach (9th ed.). W. W. Norton. https://wwnorton.com/books/9780393920772