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DESIGNING PRODUCTS AND SERVICES FOR CONSUMER WELFARE: THEORETICAL AND EMPIRICAL ISSUES

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In this paper we examine the theoretical and empirical issues that arise for a *public-sector* decision maker who wishes to use the target population's preferences as an input for designing new products and services. The marketing literature suggests using essentially the same approach as that for the *private-sector* problem, with one exception. Instead of maximizing profits, share or volume, the *sum-of-benefits* to society is maximized. However, the social welfare literature has suggested several other measures of welfare and shows that no single welfare function dominates all others. Therefore, to choose an appropriate welfare function to maximize the decision maker must first examine the theoretical and empirical similarities between the alternatives.

For six prominent welfare functions, we examine the theoretical differences in terms of the notion of *fairness* promoted and the kind of *preference data required*. Empirically, we examine the similarities in social rankings and first choices induced by these welfare functions under various preference configurations. We also examine their sensitivity to measurement error and preference normalization.

(New Products; Social Welfare)

1. Introduction

Consider the case of a *public-sector* decision maker (DM) who would like to choose the best physical and operational characteristics for a town library that yields the greatest benefit to the citizens. The *prescriptive decision analysis* approach suggests basing the decision on an assessment of the DM's (or a decision making committee's) perceptions about the desirability of competing alternatives (see, e.g., Keeney and Raiffa 1976, Chapter 8). As Hammond and Adelman (1976) and Parker and Srinivasan (1976) observe, the principal limitation of this approach is that the preferences of the target population, although central to the decision, are not *directly* reflected in the DM's evaluation of alternatives. On the other hand, extending the procedures of prescriptive decision analysis is often too cumbersome when the number of respondents is even moderately large (Keeney and Raiffa 1976, p. 543, Laskey and Fischer 1987).

Structurally, the public-sector problem is very similar to that of designing new products in the *private sector*. Recognizing that research can "challenge some managers' most fundamental assumptions about their customers" (Kotler and Andreasan 1987), marketing researchers have successfully developed measurement and evaluation procedures

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suitable for basing such decisions on consumer preferences, instead of the perceptions of a manager (or a management committee). Typically, the recommended approach for the private-sector problem is to (i) define objective(s), (ii) assess customer preferences, and (iii) evaluate, using customer preferences, the feasible alternatives, in terms of the chosen objective(s). Over the years a great deal of research has been done for each of these three stages. Various objectives, primarily relating to the private-sector problem (e.g., volume, market share, profit) have been examined (e.g., Green, Carroll and Goldberg 1981; Zufryden 1977; Hauser and Simmie 1981). Methods for assessing the preferences of a large number of people have been developed, the most successful from a practical standpoint being conjoint (hybrid-conjoint) analysis (Green and Srinivasan 1978, Green, Goldberg and Montemayor 1981, Green 1984).

Given the recognizable similarity between the private- and public-sector problems, marketing researchers (Dobson and Kalish 1988, Green and Krieger 1985, Kotler and Andreasan 1987, chapter 13, Parker and Srinivasan 1976) have suggested using essentially the same procedures for public-sector problems, with one important modification. The objective function is changed to reflect the decision maker's concern with the welfare or "social profit" (Lovelock and Weinberg 1984) of the target population. Marketing researchers have typically chosen to maximize the *utilitarian function* which orders alternatives according to the total benefit (sum of utilities) received by the target population.

However, we contend that this translation is incomplete in some important respects. *First*, equating society's welfare with the *utilitarian* function may not necessarily be appropriate. There are many possible welfare functions, of which the utilitarian is only one. Each welfare function differs not only in terms of how it operationalizes social welfare, but also in terms of the implied distribution of benefits (*fairness*) among individuals or constituencies, a critical consideration in public-sector decisions (Kotler and Andreasan 1987). Further, a substantial body of results in the social welfare literature shows that every possible welfare function has at least one theoretically undesirable consequence. Often, it has many. For instance, the utilitarian function can be insensitive to the preferences of the majority. For example, consider the case of a township planning to build its own library. Suppose that currently there is an agreement with an adjoining township to use their library, and that there are three feasible, new alternatives (differing in terms of kinds of books, number of books, and video services). Also, suppose there are 5 segments with relative sizes and preferences as shown in Example A.1 in the appendix. As Weaver and Weaver (1979) point out, considerations of social welfare are especially pronounced in public-library decisions because they are typically funded through general tax revenues. If social welfare is equated with the utilitarian function, as suggested by the marketing literature, the township should choose option A. But note that the majority of the constituents prefer *each* of the other options to A. As Drucker (1973) notes, in a democratic society, the DM might be hard pressed to justify the choice of option A, especially if the minority (segments 1 and 4) which stands to benefit from A is already considered to be unusually fortunate. Consequently, it is important to examine measures of social welfare other than the utilitarian, and to compare the alternative welfare functions (including the utilitarian) in terms of their conceptual similarities and theoretical properties.

Second, even if the DM has society's mandate to sacrifice the wishes of the majority in favor of the greater total benefit, using *cardinal utility measures* (such as those obtained from conjoint analysis or lottery procedures) is still inappropriate. As we shall see in §2.2, to use the *utilitarian* objective we should be able to compare the benefits gained by one person against those gained by another. That is, we should be able to judge, for example, whether constituency 1 will benefit more than constituency 2 if option A is selected. Cardinal (interval-scaled) utility measures do not permit such comparisons. The important thing to note is that, unlike the private-sector problem, the measurement methodology employed either constrains, or depends crucially upon, the objective function chosen to maximize social welfare.

Third, in addition to understanding the theoretical differences between welfare functions, it is also important to examine the extent to which such differences manifest themselves under various configurations of individual preferences (Bordley 1983, Chamberlin and Cohen 1978, Fishburn 1986). For example, for particular configurations of individual preferences, it is *possible* that the utilitarian choice is also the most preferred by a majority. If the differences between social evaluations arise in only rare instances, the task of choosing the welfare function for a particular situation is simplified. However, if the social evaluation often differs across welfare functions, then it is important to understand the patterns of preference configurations under which they do so. Further, because preference measures contain error, it is important to examine the robustness of each welfare function to measurement error. A function which is sensitive to measurement error can provide social evaluations which are not consistent with even its own notion of fairness. However theoretically attractive such a function may be, it is of little practical use.

The primary purpose of this paper is to provide theoretical and empirical results which can guide the DM and the marketing researcher in choosing an appropriate welfare function, and collecting the required data. Specifically, the objectives of the paper are to

(*i*) *Examine the theoretical similarities and differences amongst six prominent welfare functions*. Formal comparisons of the properties of various welfare functions are available in the social-welfare literature (Felsenthal and Moav 1988, Plott 1976, Richelson 1981, 1979, Sen 1970, Yaari 1981). In our evaluation (§2.2), we focus on the implications of each of these functions for preference measurement, i.e., the *formal input data requirements*. For each welfare function we also examine the notion of *fairness* embodied in the resulting social ordering of alternatives. An important conclusion of this analysis is that measuring interval scale preferences, preferably using conjoint analysis, allows the DM the greatest flexibility in choosing a welfare function and in evaluating the possible alternatives.

(*ii*) *Evaluate the performance of the welfare functions under a wide variety of empirical conditions*. The analysis in §2 shows that differences in the notion of fairness favored by a welfare function are based primarily upon how it (a) treats information about the intensity with which a given individual prefers one alternative versus another, and (b) resolves conflicts in preferences across individuals. Variations in the customers' preference intensity, and the need to market to an entire but heterogenous society have also been noted by marketers as being particularly prevalent in nonbusiness situations (Rothschild 1979). Consequently, in §3, using a Monte Carlo simulation, we examine the similarities among evaluations of alternatives by different welfare functions under alternative configurations of *preference intensity* and *preference conflict*. Also, we empirically assess the robustness of each welfare function to measurement error. Finally, we examine the robustness of social rankings and choices for the utilitarian and Rawls functions when cardinal preference data, rather than the formally required interpersonally comparable data, are used to evaluate product alternatives.

2. Welfare functions: Fairness Considerations and Data Requirements

2.1. *Fairness*

Fairness is a central consideration in public-sector problems, reflecting social preferences over alternative distributions of benefits across a target population. Although many notions of fairness are prevalent, two are generally regarded as most significant. The first is the *Condorcet criterion* (Black 1958, Chamberlin and Cohen 1978, Fishburn 1973), according to which it is *unfair* to select an alternative that is *less preferred* to another by a majority of consumers. That is, if a majority prefers C to B, then B should not be the social choice;

and if a majority prefers C to all other feasible alternatives, then C should be the social choice. For Example A.1, in the appendix, option C is preferred to every other option by a majority. However, this need not always occur, since Arrow's (1950) general possibility theorem shows that no social welfare function *always* satisfies the Condorcet criterion. Further, a Condorcet "winner" need not exist for every configuration of individual preferences. For example A.2, in the appendix, the majority relation is intransitive. Given any option, it is possible to find at least one other item which is preferred by a majority.

When a Condorcet winner does not exist, several proposals for "completing" it have been proposed. One particularly attractive proposal due to Copeland (1951) suggests that the alternatives be ordered according to the number of items over which they are preferred by a majority of individuals. Note that if a Condorcet winner exists, then it will also be a Copeland winner. Consequently, in the Monte Carlo simulation (§3), the Copeland criterion will be used to compare welfare functions in terms of their departure from the "majoritarian" notion of fairness.

Equity is a second prominent notion of fairness. When a relevant input can be measured (e.g., taxes paid, investments made, land ceded to a project), a distribution of returns (e.g., adverse environmental impact, health benefits) in proportion to inputs is said to be *equitable* (Walster, Berscheid and Walster 1973). For many public-sector problems, such as the design of rural health facilities, parks, zoos and public schools, it is difficult to *define*, much less *measure*, inputs. A common approach in such cases is to define equity as the *equal* distribution of benefits across target consumers. In the theoretical comparisons in §2, a welfare function will be termed *inequity averse* if, for a given level of total benefit, an equal distribution of benefits is preferred to any unequal distribution, and as *inequity neutral* if any distribution of benefits is equally preferred (Harvey 1985). Note that because benefits are compared across individuals, equity considerations necessarily entail interpersonal comparisons of utilities. Besides the Condorcet criterion and equity, idiosyncratic notions of fairness are implied by some welfare functions. These, too, are discussed below.

2.2. *Social Welfare Functions*

Formal comparisons of the properties of various welfare functions are provided by Plott (1976), Richelson (1981, 1979), Sen (1970) and Yaari (1981). Here, we limit our attention to the notions of fairness and the data requirements implied by *six* welfare functions that have received significant attention in the social-welfare literature: *plurality*, *approval voting*, *Borda count*, *Nash*, *Rawls and utilitarian* (Bordley 1983, Feldman 1980).

A social welfare function maps a set of individual preferences into a social preference order. The differences among the functions arise from how each function uses/requires information about *intrapersonal preference intensity* and *interpersonal comparability*, in the individual preferences data.

Intrapersonal *preference intensity* refers to the extent to which differences in preferences between alternatives can be ordered. For example, if individual preferences are measured as rank orders, the utility difference between the fifth and second ranked alternatives is at least as great as that between the third and fourth ranked alternatives. If individual preferences are measured on an interval (cardinal) scale, we also can compare the ratio of utility differences between pairs of alternatives; and if individual preferences are measured on a ratio scale, we can compare the ratios of utilities for pairs of alternatives.

Interpersonal comparability refers to the extent to which the benefits different people (or constituencies) receive from an alternative can be compared. For example, *co-ordinally comparable* individual utilities allow us to assess whether constituency 1 is better-off than constituency 2 when option A is chosen, but does not permit assessment of the *amount* by which constituency 1 is better-off. On the other hand, interval scaled preference measures do not permit *any* interpersonal comparisons. Together, intrapersonal preference intensity and interpersonal comparability define the formal input data requirements for each welfare function.

Each of the six welfare functions examined can be decomposed into a *scoring function*, which determines the required information regarding intrapersonal preference intensity, and an *aggregation function*, which determines the required information regarding interpersonal comparability of preferences. More formally, let **X** denote a set of n alternatives, and let **I** denote a set of m consumers evaluating the items in **X**. Let $u_i(x)$ denote individual i's utility (i.e., preference measure) for item $x \in \mathbf{X}$ (the measurement scale of $u_i(x)$ will be subsequently defined for each welfare function). A *social welfare function* assigns a value $w(x)$ to each alternative $x \in \mathbf{X}$ based on the preferences of the individuals in **I**. For each welfare function, the *scoring function* f: assigns idiosyncratic scores $f_i(x)$, and the *aggregation function* w: combines the individual scores into a social evaluation, $w(x) = w(f(x))$, for each alternative $x \in \mathbf{X}$. For example, the binary scoring function

$$f_i(x) = \begin{cases} 1 & \text{if } x \text{ is preferred to } y, \qquad x, y \in \mathbf{X}, \\ 0 & \text{otherwise}, \end{cases} \tag{1}$$

assigns a score 1 to item $x \in \mathbf{X}$ only if it is most preferred by individual $i \in \mathbf{I}$ among the alternatives in **X**. No other intrapersonal preference information is required. The aggregation function

$$w(x) = \sum_{i \in \mathbf{I}} f_i(x), \qquad x \in \mathbf{X}, \tag{2}$$

counts the *number of individuals* who prefer item x the most among the alternatives in **X**. Note that the aggregation function does not require any information about interpersonal comparability of preferences. Thus, idiosyncratic first-choice data are sufficient to determine the social ordering of alternatives in **X**.

Table 1 compares the scoring and aggregation functions, the data requirement, and the fairness considerations for the six welfare functions. A brief discussion of each welfare function follows.

TABLE 1

Summary of Scoring and Aggregation Functions, Data Requirements, and Fairness Considerations for Six Welfare Functions

Welfare Function	Scoring Function	Aggregation Function	Fairness	Data Requirements
Plurality	$f_i(x) = \begin{cases} 1 & \text{if } u_i(x) \geq u_i(y) \text{ for all } x, y \in \mathbf{X}, \\ 0 & \text{otherwise} \end{cases}$	$w(x) = \Sigma_{i=1}^{I} f_i(x)$	Can pick Condorcet loser	First choice
Approval Voting	$f_i(x) = \begin{cases} 1 & \text{if } u_i(x) \geq u_i(x_u), \\ 0 & \text{otherwise} \end{cases}$	$w(x) = \Sigma_{i=1}^{I} f_i(x)$	Picks Condorcet winner at least as often as Plurality	Set of acceptable alternatives
Borda Count	$f_i(x) = r_i(x)$	$w(x) = \Sigma_{i=1}^{I} f_i(x)$	Never picks Condorcet loser. Inequity neutral	Rank order
Nash	$f_i(x) = u_i(x) - u_i(x_u)$	$w(x) = \Pi_{i \in \mathbf{I}} f_i(x)$	Can be "vetoed" Inequity averse	Cardinal utilities
Rawls	$f_i(x) = u_i(x)$	$w(x) = \min\{u_i(x) \mid i \in \mathbf{I}\}$	Maximizes benefit to least advantaged Inequity averse	Co-ordinally comparable utilities
Utilitarian	$f_i(x) = u_i(x)$	$w(x) = \Sigma_{i=1}^{I} f_i(x)$	Maximizes total benefit. Inequity neutral	Cardinally comparable utilities

Plurality. The alternative most preferred by most people is the plurality choice. Every individual's first choice is assigned the same score (1), and is weighted equally by the aggregation function. Consequently, preference intensity need not be assessed, and no interpersonal comparisons are required. Only first-choice data are needed for determining the social preference order. If the number of alternatives being evaluated is small, consumers can be directly asked to provide their first choices. However, if the set of alternatives is large (e.g., consists of a large number of multi-attribute alternatives), indirect preference measurement procedures (e.g., conjoint or hybrid-conjoint analysis) may be used to *infer* individual first-choices.

Although considered "democratic," a plurality choice need not be fair by the Condorcet criterion. In fact, as Example A.1 in the appendix shows, the plurality winner (option A) can be a Condorcet loser to *every other alternative*. As for equity, note that for those individuals who do not prefer the plurality choice most, this function is indifferent between picking their second choice or their least preferred choice. Thus, if the township merely based its decision on a referendum of first choices, rather than a more complete listing of preference orders, a majority of the citizens would be dissatisfied with the choice. Finding tax support for such an alternative may then prove especially difficult.

Approval voting. This function is equivalent to the *share-of-choices* criterion, commonly used in conjoint choice simulators (e.g., Green, Carroll and Goldberg 1981, Kohli and Krishnamurti 1987, Zufryden 1977). Thus, to the extent that it is a desirable welfare function, maximizing share-of-choices in private-sector decisions also maximizes consumer welfare.

Approval voting ranks an alternative $x \in \mathbf{X}$ according to the number of people who prefer it to their idiosyncratic status-quo option, x_{is}. Note that the scoring function merely counts whether (1) or not (0) an individual prefers an item to his/her status-quo. Therefore, no measure of preference intensity is required. The aggregation function equally weights each individual's binary (1/0) score for an alternative, and hence treats these scores *as if* they are comparable. Thus, to use this welfare function each individual needs to classify alternatives into "acceptable" and "unacceptable" categories. If only a few alternatives are under consideration, direct evaluations (e.g., "pick-any-of-n" data) can be used. For larger numbers of alternatives, indirect preference-evaluation methods (e.g., conjoint simulations) that permit inferences regarding acceptability of alternatives over status-quo can be used.

Approval voting also is not *always* fair by the Condorcet criterion (Saari 1986). As Example A.1 in the appendix shows, it can fail to pick a Condorcet winner (option C) even when one exists (the approval voting choice is option B). However, the Condorcet winner is selected by approval voting in *at least* every case that it is by plurality voting (Fishburn 1973). As for equity, note that for those individuals who do not prefer the approval-voting choice to their status-quo, the preference order among the remaining alternatives is irrelevant. The function is indifferent between picking an alternative which is only slightly less preferred versus another which is much less preferred than status-quo by an individual.

Borda Count. Unlike plurality and approval voting, the scoring function for the Borda count weights the alternatives according to their *inverse rank* for a consumer, $r_i(\cdot)$. That is, the score assigned to an item by an individual decreases from n (the total number of alternatives in $\mathbf{X}$) for the most preferred item to 1 for the least preferred item for an individual. Note that the difference in scoring weights between alternatives x and y is *no less* than that between alternatives z and w, whenever $r_i(x) \leq r_i(z) \leq r_i(w) \leq r_i(y)$. That is, the scoring function reflects *ordinal preference intensity*. The aggregation function treats the scoring weights (i.e. the inverse ranks) as if they are interpersonally comparable. Consequently, ordinal preference data are necessary to evaluate alternatives using this welfare function. The data collection task is more complex than for plurality and approval voting because a complete ranking of alternatives must be assessed. Indirect preference measurement methods like conjoint analysis, which permit estimation of rankings from parameterized preference functions can also be used, especially when the number of alternatives is large.

Although it, too, does not always satisfy the Condorcet criterion, the Borda count is the only welfare function using ordinal preferences that never selects a Condorcet loser, and never ranks the Condorcet winner the lowest among alternatives (Saari 1986). It is *inequity neutral* because, for a given sum of inverse ranks, it is indifferent between an alternative which is equally ranked by all individuals, and an alternative which is ranked high by some individuals and low by others.

Nash. The Nash social welfare function (Kaneko and Nakamura 1979) is based on Nash's (1950) solution for cooperative games. The score $f_i(x)$, assigned to item $x \in \mathbf{X}$ is the *incremental utility* individual $i \in \mathbf{I}$ receives from item x over his/her status-quo alternative x_{is}. Thus, the scoring function reflects cardinal preference intensity, and hence requires at least interval scaled assessment of individual preferences. The aggregation function orders the alternatives according to the *product of incremental utilities* across individuals. The ordering of alternatives induced by the welfare function is unchanged by affine transformations of the individual utility functions, so that interpersonal comparability of preferences is not required. Because the welfare function *does* consider the intensity of consumer preferences but *does not* require interpersonal utility comparisons, preferences may be assessed using procedures like conjoint analysis that yield interval-scaled preference estimates.

The Nash welfare function is *inequity averse*, and the product of incremental utilities is largest when each individual has an equal share of a given sum of incremental utilities. However, note that even if only one individual slightly prefers his/her status-quo to an alternative which is everyone else's first choice, the alternative will not be selected by the Nash function. Each individual, effectively, gets the power to veto the desires of all other individuals. Also, because the product of an even number of negative values is positive, an item which is less preferred than status-quo by any even number of individuals would be socially preferred to another alternative which is less preferred to the status-quo by a smaller, odd number of individuals. Therefore, in order to implement this welfare function, *every item* $x \in \mathbf{X}$ must be preferred to status-quo by *every individual* $i \in \mathbf{I}$. This requirement can prove to be quite restrictive, and as in the simulation reported in §3, can often result in the absence of any alternative that is feasible by the Nash criterion.

Rawls (*Lexical Maximin*). The Rawls criterion evaluates each alternative according to its utility to the individual who likes it the least. The socially-preferred item is the one for which the minimum utility is greatest across individuals. To use the welfare function, one needs to determine whether the worst-off individual for one alternative is better-off than the worst-off individual for another alternative. However, the *extent* to which one individual is better-off than another need not be assessed. Thus, co-ordinally comparable utility functions (Arrow 1977) are needed for the Rawls welfare function.

An important problem with the use of Rawls' criterion is that none of the measurement procedures commonly used by marketing researchers (e.g., conjoint/hybrid-conjoint analysis) are strictly appropriate, since these do not provide interpersonally-comparable preference measures. Direct (Pessemier 1963) or indirect (Parker and Srinivasan 1976) pricing-out methods have been treated *as if* they yield cardinally comparable utilities. However, the comparability depends crucially upon the assumption that utility for money is the same across individuals. Alternatively, *normalized*, conjoint utility estimates have been treated *as if* they are interpersonally comparable (Green and Krieger 1985). However, this approach assumes that each consumer obtains the same utility from his/her most-preferred alternative in X. In §3 we empirically test the extent to which the normalization affects the rank order and first choices for the Rawls criterion.

Rawls (1971) argues that this function is fair because of its concern for the least-advantaged person. However, as Example A.1 in the appendix shows, it can be overly solicitous of the disadvantaged. Even though the majority prefers option C to any other, the low preferences of constituency 1 for option C prevent it from being the social choice (the Rawls choice is option A). As in the case of the Nash welfare function, the preferences of a majority can effectively be overridden by the preferences of a single individual. Finally, like Nash, this function is also *inequity averse*, because it most prefers an equal distribution of a fixed sum of utilities.

Utilitarian (*Sum of Benefits*). As previously noted, marketing studies have used this function exclusively to measure social welfare. This function ranks items according to the total benefit to the target population. Both preference intensity and interpersonal comparisons play a role in determining the social desirability of an alternative. Cardinally comparable utilities are necessary, only *identical*, positive linear transformations across consumers preserving the induced social preferences over alternatives induced by the welfare function. As for Rawls, commonly used measurement procedures such as conjoint/hybrid-conjoint analysis are not strictly appropriate because they do not reflect interpersonal comparisons of utilities. In §3, we assess the extent to which treating normalized preferences as if they are interpersonally comparable affects the rank order of the induced social preferences.

Harsanyi (1955) discusses philosophical reasons for the fairness of a utilitarian choice. The function is *inequity neutral* because it is indifferent to the manner in which total benefits are distributed across consumers. As Example A.1 in the appendix shows, this can lead to selecting an alternative that a few consumers like very much, but most like little. The majority prefers any other option to A, but the strong preferences of constituencies 1 and 4 (i.e., of 130 out of the 870 individuals) result in its selection by the utilitarian function.

2.3. *Data Requirements and Empirical Considerations*

The above discussion identifies important differences in the data requirements for the six welfare functions. The utilitarian and Rawls welfare functions require interpersonal utility comparisons, which are generally difficult to obtain. The Nash welfare function uses idiosyncratic, interval-scaled data, which can be obtained using conjoint analysis. However, the Nash welfare function can only be used in situations where each candidate item is preferred to the status-quo option by each consumer. The rank-order data for the Borda welfare function, the pick-any-of-*n* data for approval voting, and the first-choice data for plurality voting can be directly obtained from a sample of target consumers. However, if there are a large number of feasible alternatives, direct assessment can be cumbersome. For example, Brown (1984) describes the problem of locating a dam and reservoir in terms of 14 attributes. Direct preference assessment of all possible dams and reservoirs described by a factorial combination of the attributes is infeasible. In such situations, conjoint (hybrid conjoint) procedures can be used to reduce the data collection task and to estimate multi-attribute utility functions from which the ordinal or first-choice preferences can be estimated.

The theoretical comparisons of the preceding section also suggest that each welfare function embodies a different notion of welfare and fairness, and that none dominates another in terms of all reasonable, theoretical criteria. Thus, on conceptual grounds alone, one cannot recommend one welfare function over another. A DM's proclivity towards a certain notion of welfare must be central input to the choice of a welfare function in any practical application. However, as we have argued in §1, there are additional empirical issues that a DM must consider in choosing among the welfare functions for any practical application.

First, the extent to which consumer preferences are actually in conflict, and the extent to which consumers do have different preference intensities, is likely to affect the need to select one welfare function or another. If all consumers have identical preferences, all welfare functions yield the same social evaluations. As individual preferences diverge, differences in social evaluations become more likely across welfare functions. Similarly, as preference intensity across alternatives and consumers increases, social evaluations by two welfare functions are more likely to differ if one uses information about preference intensity and the other does not. For example, the Borda and utilitarian functions are similar (both are based on the sum of preference scores), except that Borda uses ranks and utilitarian uses cardinally comparable utilities of alternatives. Thus, if the differences in utilities between pairs of alternatives are comparable, the Borda and utilitarian welfare functions are likely to provide similar social evaluations. As these utility differences increase, the Borda and utilitarian evaluations are likely to diverge. Therefore, from a practical standpoint, it is useful to know the extent to which similarities in social evaluations are affected by increasing differences in preference conflict and preference intensity. If the social evaluations across welfare functions differ significantly only under extreme conditions of preference conflict and high divergence in preference intensity, choosing among welfare functions may be more a theoretical than a practical issue.

Second, a welfare function that appears attractive based on its formal properties may not be particularly useful if its evaluations are not robust to error in individual preferences, and therefore are not consistent even with its own notion of welfare. The sensitivity of a welfare function to error is particularly important in situations where the (ordinal or cardinal) preferences of consumers are inferred from preference-function estimates, and therefore contain both measurement and estimation error. Such situations arise when cardinal utility estimates are necessary to use a welfare function (e.g., Rawls, Nash, utilitarian) or when the number of alternatives evaluated is so large as to preclude direct assessment of ordinal preference data (e.g., Borda, approval or plurality voting).

Third, two of the preceding welfare functions, Rawls and utilitarian, require interpersonally comparable preferences, which are difficult to obtain in practice. Although the formal data requirements suggest that it may be difficult to implement the two welfare functions, a DM is likely to be interested in the sensitivity of social evaluations to violations of these formal data requirements. For instance, if their social evaluations are not significantly affected by treating normalized, interval-scaled utilities as interpersonally comparable, the Rawls and utilitarian welfare functions may be suitable to use with normalized conjoint data, which are easily obtained.

Finally, none of the six welfare functions considered guarantee a Condorcet winner. A DM who is sensitive to the preferences of majorities of consumers would like to know which welfare functions are more likely in practice to yield social evaluations that are consistent with the preferences of a majority.

3. Empirical Issues

3.1. *Simulation Design*

We examine the four empirical issues discussed in §2.3 in a simulation study, varying the number of consumer segments (3, 4, 7), number of consumers per segment (5, 25, 50), and number of alternatives (5, 10, 50). The preference intensity for a segment, reflected in the standard deviation of the segment utilities across alternatives, is varied to reflect four conditions: equal intensity for each segment; moderate differences across segments; higher intensity for one segment; and sharp differences across segments. Preference conflict is manipulated by systematically changing the shape of the Pareto frontier in the individual-utilities space. The Pareto frontier identifies alternatives that are no less preferred than any other alternative by all individuals. Each segment's utility for each alternative is selected by a point on the Pareto frontier. The sharpest preference conflict is generated by assuming that items lie on a linear Pareto frontier, reflecting a perfectly negative correlation between individual utilities for an item. Lesser preference conflict is generated by assuming that the items lie on a circular Pareto frontier, reflecting a correlation of −0.92 between the utilities obtained by two individuals from an item. A random Pareto frontier, reflecting varying degrees of preference conflict, is also generated. (For an axiomatic justification of this operationalization, see Axelrod 1970.) Error (low, moderate, high) is added to each segment's preference for each alternative to generate errorfull preferences, reflecting a composite of measurement and estimation error. Finally, variation in the consumer preferences for each segment is introduced to reflect within-segment preference heterogeneity. Each design factor is independently varied in a main effects, fractional factorial design (Addelman 1962). Five replications are obtained for each of the 32 resulting combinations. The similarities between the social evaluations for each pair of welfare functions, and between a welfare function's error-free and errorfull social evaluations, are examined using two criteria: (i) the similarity in the social rankings of the alternatives, measured using Kendall's tau correlation, and (ii) the proportion of first-choice agreements. The similarity in rankings is important if the welfare functions are used to screen product concepts at early stages of development of a product or service. A similar ranking of alternatives suggests that items screened for evaluation by one welfare function (or under a certain level of preference error) are likely to be similar to items screened by another welfare function (or under an alternative level of preference error). The first-choice agreements are useful if the welfare functions are used to select a single best item to be offered to customers. High first-choice agreements suggest that an item selected by one welfare function (or under a certain level of preference error) is also likely to be selected by another welfare function (or under an alternative level of preference error). Details of the simulation plan and results are available from the authors. Below, we discuss the principal conclusions suggested by the simulation.

3.2. *Results*[1]

Preference conflict and preference intensity. Table 2 shows that as conflicts in segment preferences increase, so do differences in the social rankings and first choices by different welfare functions. If the Pareto frontier is circular, the welfare function rankings are most similar (e.g., the tau value for social rankings by the Rawls and utilitarian welfare functions is twice as high if the Pareto frontier is circular than linear). First-choices agreements are generally low, except for the Borda-approval voting and Borda-utilitarian pairs. Thus, if a DM is interested in screening alternatives, using the Borda, approval voting and utilitarian welfare functions is likely to result in similar evaluations, even if there is high preference conflict. The differences are likely to be more pronounced among the three welfare functions if the objective is to select a single-best item. Plurality and Rawls appear to represent separate and distinct types of welfare functions. Even if preference conflict is low, they provide social rankings and social choices dissimilar to each other's and to those obtained from the utilitarian, approval voting and Borda welfare functions.

Table 3 shows that preference intensity has a less pronounced effect than preference conflict on similarities among welfare function rankings. The agreements in social rankings are lowest when one segment has higher preference intensity or when there are sharp differences in preference intensities. First choice agreements are generally low, except for the Borda-approval voting and Borda-utilitarian pairs of welfare functions.

[1] The Nash welfare function is not included in these and subsequent results because it could not be implemented, each feasible alternative being worse than the status-quo for at least one individual.

Overall, the best compromise appears to be the Borda welfare function in the sense that it provides the best approximation of the social rankings and first choices of any other welfare function across the preference conflict and preference intensity conditions.

Error in preferences. The social evaluations and first choices for each welfare function are affected only marginally by the presence of low error (Table 4), which is comparable to the level of error typically used in conjoint simulations (Carmone, Green and Jain 1978, Srinivasan 1975). For both, screening multiple concepts and selecting a single best item, the welfare functions are likely to yield robust conclusions if the error level is comparable to that normally expected in preference data collected using procedures like conjoint analysis.

Increasing the error in preferences further affects, to varying degrees, the social rankings for all welfare functions. Introducing moderate levels of error in preferences affects only marginally the social rankings for the Borda and utilitarian welfare functions, but affects more significantly the social rankings for the other welfare functions. At the high level of error, the social rankings depart still further from the error-free social rankings. Only the utilitarian welfare function retains a reasonably high level of association (tau = 0.84) with error free social rankings of alternatives. The first choices for approval voting are minimally affected by any level of error in preferences. More than any other, the first choices for the Rawls welfare function change most when preferences contain moderate or high levels of error. Although plurality voting, Borda and utilitarian display first choice agreements above 80 percent at the moderate error level, they deteriorate to about 60

TABLE 2

*Effect of Preference Conflict on Similarity in Social Evaluations**

	Shape of Pareto Frontier	Welfare Function: Approval Voting	Borda	Rawls	Utilitarian
Plurality	Linear	**0.07**	**0.32**	**−0.21**	**0.36**
		0.25	0.40	0.02	0.47
	Random	**0.04**	**0.34**	**−0.05**	**0.37**
		0.24	0.45	0.05	0.39
	Circular	**0.03**	**0.48**	**−0.01**	**0.48**
		0.22	0.40	0.10	0.37
Approval Voting	Linear		**0.70**	**0.25**	**0.64**
			0.77	0.32	0.30
	Random		**0.77**	**0.32**	**0.60**
			0.75	0.21	0.21
	Circular		**0.79**	**0.53**	**0.75**
			0.75	0.25	0.25
Borda Count	Linear			**0.09**	**0.77**
				0.02	0.55
	Random			**0.23**	**0.79**
				0.02	0.50
	Circular			**0.32**	**0.94**
				0.12	0.85
Rawls	Linear				**0.18**
					0.05
	Random				**0.28**
					0.10
	Circular				**0.47**
					0.15

* For each pair of welfare functions, the first line (boldface) shows Kendall's Tau Correlation and the second line shows the Proportion of First Choice Agreements based on true preferences.

TABLE 3

*Effect of Patterns of Preference on Similarity in Social Evaluations**

	Pattern of Preference Intensity	Welfare Function: Approval Voting	Borda	Rawls	Utilitarian
Plurality	Equal	**0.04**	**0.33**	**−0.17**	**0.37**
		0.22	0.35	0.07	0.32
	One Higher	**0.04**	**0.35**	**−0.14**	**0.36**
		0.25	0.50	0.07	0.32
	Sharp Difference	**0.10**	**0.42**	**0.01**	**0.44**
		0.25	0.47	0.00	0.50
	Moderate Difference	**−0.02**	**0.38**	**−0.01**	**0.39**
		0.22	0.37	0.07	0.47
Approval Voting	Equal		**0.76**	**0.39**	**0.73**
			0.77	0.32	0.30
	One Higher		**0.77**	**0.32**	**0.60**
			0.77	0.25	0.25
	Sharp Difference		**0.75**	**0.34**	**0.61**
			0.75	0.25	0.25
	Moderate Difference		**0.76**	**0.39**	**0.66**
			0.72	0.17	0.17
Borda Count	Equal			**0.21**	**0.84**
				0.05	0.70
	One Higher			**0.08**	**0.72**
				0.02	0.47
	Sharp Difference			**0.25**	**0.80**
				0.05	0.57
	Moderate Difference			**0.35**	**0.92**
				0.07	0.65
Rawls	Equal				**0.35**
					0.07
	One Higher				**0.20**
					0.12
	Sharp Difference				**0.28**
					0.05
	Moderate Difference				**0.45**
					0.15

* For each pair of welfare functions, the first line (boldface) shows Kendall's Tau Correlation and the second line shows the Proportion of First Choice Agreements based on true preferences.

percent if preferences have high error. Thus, if the level of error is significantly higher than is normally expected in conjoint data, the utilitarian and Borda welfare functions appear to be the most robust for selecting multiple product concepts for further evaluation. However, if the objective is to select a single, optimal item, approval voting appears to be the most robust to error, Rawls the least robust.

Normalization. If error alone is added to consumer preferences, the average tau correlation between errorfull and error-free social rankings is 0.92 for the utilitarian welfare function, and is 0.82 for the Rawls welfare function. If each individual's errorfull preferences are normalized such that the utility difference between each customer's (idiosyncratic) most and least preferred alternatives is equal, the average tau correlation between (normalized) errorfull and (nonnormalized) error-free social rankings is 0.82 for the utilitarian welfare function, and is 0.67 for the Rawls welfare function. Thus, on average, normalizing errorfull preferences leads to substantial departure from true social rankings for the Rawls welfare function. This effect is less pronounced for the utilitarian

TABLE 4

*Sensitivity of Welfare Functions to Measurement Errors**

	Level of Error		
	Low	Moderate	High
Plurality	**0.91**	**0.83**	**0.70**
	0.90	0.81	0.62
Approval Voting	**0.93**	**0.84**	**0.67**
	0.98	0.97	0.96
Borda Count	**0.95**	**0.91**	**0.73**
	0.90	0.81	0.62
Rawls	**0.95**	**0.84**	**0.64**
	0.90	0.73	0.55
Utilitarian	**0.96**	**0.93**	**0.84**
	0.87	0.86	0.62

* The first line (boldface) for each function is the Kendall's Tau Correlation between social rankings based on *true* and *measured* utilities. The second line is the Proportion of First Choice Agreements.

welfare function, but is by no means negligible. These results suggest that it is not appropriate to screen product concepts using the Rawls welfare function under the assumption that normalized utility estimates are interpersonally comparable. The utilitarian welfare function is more robust, but still departs significantly from true rankings of items, if used for concept screening with normalized utility estimates.

Both the utilitarian and Rawls first choices change substantially if normalized, errorfull preferences are used instead of nonnormalized, error-free preferences. The average first-choice agreement is 0.67 for the utilitarian welfare function, and is 0.60 for the Rawls welfare function. Thus, for selecting a single, optimal item, neither the Rawls nor the utilitarian welfare functions is suitable to use with normalized utility estimates.

Similarity to Copeland criterion. Each welfare function's ranking of alternatives was compared to the ranking by the Copeland criterion, first using nonnormalized, error-free utilities, then using normalized, error-full utility estimates. The social rankings for the Borda and utilitarian welfare functions are similar to the Copeland rankings of alternatives if nonnormalized, error-free utilities are used (average tau = 0.93 and 0.90 for Borda and utilitarian, respectively). Introducing error and normalizing utilities reduces similarity with Copeland rankings of the utilitarian rankings (average tau = 0.80), but not of the Borda rankings (average tau = 0.96). The Rawls and plurality voting welfare functions produce social rankings that are dissimilar to the rankings obtained by the Copeland criterion, both with nonnormalized, error-free utilities (average tau = 0.41 for both Rawls and plurality voting) and normalized, errorfull utilities (average tau = 0.23 and 0.37 for Rawls and plurality voting, respectively). Approval voting lies in between for both nonnormalized, error-free preferences (average tau = 0.79) and normalized, errorfull preferences (average tau = 0.76). Thus, as far as the empirical consistency with a majoritarian notion of fairness is concerned, for concept evaluation, the utilitarian and Borda welfare functions appear to perform best. The first choices of each welfare function exhibit little agreement with the first choices by the Copeland criterion, except for the Borda welfare function (average tau = 0.88 and 0.85 for nonnormalized, error-free, and normalized, errorfull utilities, respectively). Thus, if a single optimal item is to be selected, consistency with the choice of the largest majority is reflected in the Borda welfare functions, but not in the others.

Taken together, these results suggest that the Nash and Rawls functions have limited practical use for consumer-welfare decisions (see Table 5 for a summary of the empirical

TABLE 5

*Summary of Simulation Results**

Welfare Function	Measurement Error	Empirical Similarity	Robustness to Normalization	Similarity to Copeland Criterion
Plurality	**Robust**	**Not similar to any other function**	**NA**	**Low**
	Robust	Not similar to any other function		Low
Approval Voting	**Robust**	**Moderately similar to Utilitarian and Borda**	**NA**	**High**
	Robust	Similar to Borda		Low
Borda Count	**Robust**	**Most similar to Utilitarian and Approval Voting**	**NA**	**High**
	Robust	Most similar to any other function		High
Rawls	**Robust**	**Not similar to any other function**	**Sensitive**	**Low**
	Moderately Robust	Not similar to any other function	Sensitive	Low
Utilitarian	**Robust**	**Most similar to Borda and Approval Voting**	**Moderately Robust**	**High**
	Robust	Moderately similar to Borda	Moderately Sensitive	Moderate

* For each welfare function the boldface remarks are based on **Kendall's Tau Correlation**. The second set of remarks are based on Proportion of First Choice Agreements.

results). If the interest is in determining a social ranking, the utilitarian function can be implemented by treating normalized, interval-scale utilities as if they are interpersonally comparable. However, the utilitarian function cannot be recommended if the interest is in identifying a single first-choice alternative. For the remaining three welfare functions, (approval voting, plurality, and Borda), their robustness to measurement error suggests that they are most suitable for practical applications. But, if the DM is also concerned about similarity to the Copeland criterion, Borda is best and plurality is worst. Finally, it is noteworthy that the Borda function had the highest similarity with each of the other welfare functions. In this sense it represents the best "compromise" welfare function.

4. Discussion

Concern for society's welfare is an important objective in new product design for the public-sector (Drucker 1973, Kotler and Andreasan 1987, Lovelock and Weinberg 1984). With a few exceptions, however, such decisions have traditionally been based more on the DM's perceptions of customer preferences rather than on data collected through marketing research (Brown 1984, Permut 1980). Further, the utilitarian objective function considered by marketing researchers is only one among many possible consumer welfare functions. This paper considers six prominent welfare functions, one of which is the utilitarian. Different welfare functions require different data, and each welfare function differs in terms of its properties of fairness and equity. However, no welfare function dominates all other in terms of all desirable properties. An explicit recognition of formal differences among welfare functions is therefore a necessary first step in a public-sector DM's choice of an objective function for evaluating new products and services.

Further, to facilitate the use of customer preferences in public-sector applications it is also important to understand the empirical properties of the various welfare functions.

The simulation results, presented in this paper, provide important insights into several empirical issues. For example, knowing that the utilitarian function is sensitive to normalization for first-choice agreements, but not for ranking of alternatives, suggests that it is more useful at the concept-evaluation stage when multiple, rather than a single, item is screened for further consideration. Similarly, the Rawls function, despite its egalitarian appeal, should be used with caution because of its sensitivity to normalization and higher levels of error. Plurality voting should be used only if the preferences of a majority of constituents are not of great importance to the DM. The empirical performance of Approval voting and the Borda count suggests, in agreement with other results reported by Bordley (1983) and Fishburn (1986), that they are particularly appropriate in practical settings. The Borda count may be preferable because of its greater similarity to each of the other welfare functions and to the Copeland criterion.

From a practical standpoint, the DM may often wish to retain some flexibility about which welfare function to use, at least until after the data have been collected. A major reason for this is that the extent to which social evaluations across welfare functions differ, in terms of criteria most important to a DM, are not known until consumer preference data are collected and analyzed. If there is little difference among welfare-function evaluations on one criterion (e.g., the consistency with a majoritarian notion of fairness), the choice of a welfare function may depend upon other criteria (e.g., the utility to the least-advantaged constituency). Thus, from the standpoint of data collection, it may be best to use procedures which permit the DM to subsequently examine the social evaluations of as many welfare functions as possible. Since preferences are difficult to assess at any more than an interval scale, procedures like conjoint analysis, which yield cardinal utility estimates over multiattribute descriptions of alternatives, should provide the greatest flexibility to the DM. Such data can then be used to evaluate alternatives using welfare functions that require interval-scaled (e.g., Nash) or less than interval-scaled preferences (e.g., Borda, approval voting, plurality voting). Also, the data can be used to develop models that, like conjoint choice simulators for private sector problems (e.g., Green, Carroll and Goldberg's 1981 POSSE model), can be used to evaluate the performance of multiattribute alternatives using any welfare function. Such models can help the DM to not only assess the potential performance of preselected items but also to efficiently select optimal, multiattribute items from a large set of alternatives (e.g., Green and Krieger 1985, Dobson and Kalish 1988), evaluate the sensitivity of welfare function evaluations to perturbations in individual utility estimates, and cross-validate the evaluations by a welfare function over separate (or split) samples of consumers.[2]

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[2] This paper was received in March 1988 and has been with the authors 5 months for 2 revisions.

Appendix

This appendix presents two hypothetical examples to illustrate possible differences in social rankings and first choices for the welfare functions. In each example, the true utilities are assumed to be cardinally comparable. Also, option D represents each segment's true utility from the status-quo option (using the library in the adjoining township). Note that each option is worse than the status-quo for at least one segment. Consequently, the Nash welfare function would result in maintaining the status-quo in both examples. Finally, there is no Condorcet winner for Example A.2.

EXAMPLE A.1

True Utilities for Options

	n	A	B	C	D
Segment 1	7	10	7	1	6
Segment 2	28	5	3	4	2

	n	A	B	C	D
Segment 3	32	6	8	7	9
Segment 4	6	11	3	12	4
Segment 5	14	4	6	7	5
Social Rankings					
Condorcet		4	2	1	3
Plurality		1	4	3	2
Approval Voting		4	1	2	3
Borda		4	2	1	3
Rawls		1	2	4	3
Utilitarian		1	3	2	4

EXAMPLE A.2

True Utilities for Options

	n	A	B	C	D
Segment 1	32	5	4	2	3
Segment 2	10	5	1	3	4
Segment 3	24	5	30	15	20
Segment 4	20	12	10	25	3
Segment 5	14	5	6	8	7
Social Rankings					
Condorcet*		B, D	C, D	A	C
Plurality		1	3	2	4
Approval Voting		2	1	4	3
Borda		2	1	3	4
Rawls		1	4	3	2
Utilitarian		4	1	2	3

* In this example, there is no Condorcet winner. The entries in this line show the library options which are less preferred by a majority. For example, B and D are less preferred than A by a majority. Note that each alternative is less preferred than at least one alternative by a majority.

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