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Econometric estimation of deprivation cost functions: A contingent valuation experiment

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ABSTRACT

This paper details research to design an estimation process for Deprivation Cost Functions (DCF) using Contingent Valuation, and to apply it econometrically to obtain a DCF for drinkable water. The paper describes both the process and results obtained. The results indicate that deprivation costs for drinkable water have a non-linear relation with deprivation times. The estimated DCFs provide a consistent metric that could be incorporated into humanitarian logistic mathematical models, eliminating the need to use proxy metrics, and providing a better way to assess the impacts of delivery options and actions. The research reported in this paper is the first attempt in the literature to produce estimates of the economic value of human suffering created by the deprivation of a critical supply or service.

1. Introduction

The growing social and economic impacts of disasters add tremendous urgency to the development of effective disaster preparation and response procedures. These pressures are expected to intensify with the growing urbanization of the world population, which is resulting in increasingly large and complex metropolitan areas. Many of these population centers—rarely well prepared to respond to large disasters—are located in coastal areas, or in proximity to earthquake fault lines, increasing their vulnerability. The size and complexity of these emerging megalopolises dramatically complicate disaster response procedures. In such a context, the humanitarian logistics (HL) system will play an even more important role, having to transport and deliver larger amounts of supplies for longer distances, and in more complex and congested transportation networks. There is a wide spectrum of HL operations, from regularly programmed efforts to fight malnutrition in chronic regions to the extremely challenging operations in post-disaster environments (Holguín-Veras et al., 2012).

The common thread across all variants of HL is the desire to minimize the suffering brought about by the deprivation of critical supplies and services. This insight has been recognized by HL practitioners and researchers, who must consider alternative strategies for allocating scarce resources. In this context, relief groups strive to find the most effective way to help the population in need, while using their assets efficiently. In most cases, they make such important decisions on the basis of intuition and experience, without the assistance of analytical tools. As in other fields—such as health care policy and medical triage—these gut-wrenching decisions determine who gets help and who does not (Moskop and Iserson, 2007). For instance, the arrival of a new expensive lifesaving drug leads to difficult decisions about whether large amounts of money should be paid to save a few individuals, or whether the money is better used to improve the lives of many (New York Times, 2014). There are no easy answers to these questions. However, for the purposes of this research, it is

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important to separate ethical and philosophical debates about the allocation of resources from the practical imperatives, and the development of mathematical models primarily designed to assist decision-making. These models, as simplifications of reality, are not designed to weigh philosophical and ethical considerations (Le Menestrel and Van Wassenhove, 2004), which can only be done by the decision makers who must allocate scarce resources. Models can only provide guidance to the decision makers tasked with the many facets of response operations.

The chief role of HL mathematical modeling is to develop support tools to provide decision-makers with unbiased, reliable, and robust information to help them allocate scarce resources, often under difficult and time-critical conditions. In recent years there has been increasing interest in the development of such models. In creating any mathematical model it is crucial to ensure that the objective functions are appropriate. In terms of HL mathematical modeling, this necessitates proper consideration of human suffering and the impacts of delivery strategies. By any account, this is a very challenging proposition, with no universal consensus about the best ways to formulate the objective functions in HL models. The first worthy attempts to account for human suffering extended commercial logistic techniques to humanitarian cases. This has led to the use of penalties for late deliveries, the minimization of unmet demands, and the specification of equity constraints. Regrettably, the validity of such approaches has been called into question because they cannot correctly account for the complex non-linear effects associated with human suffering over time (Holguín-Veras et al., 2013).

Recognizing the limitations of these approaches, researchers have attempted to define and formulate novel objective functions for use in HL modeling. Gralla et al. (2014) used Conjoint Analysis of experts' preferences to define an objective function able to assess the trade-offs among the goals to be pursued when deciding on relief distribution strategies. Sheu (2014) assessed psychological impacts on beneficiaries, and proposed a disaster relief distribution model from the perspective of the survivors. Holguín-Veras et al. (2013) conducted a comprehensive analysis of the objective functions and proxy measures of human suffering reported in the literature. Because of its relevance to this paper, Holguín-Veras et al. (2013) is discussed in detail.

Holguín-Veras et al. (2013) analyzed the methodological alternatives, and concluded that welfare economics—the branch of economics that studies the economic impacts of the allocation of resources—provides the most appropriate framework to decide on the allocation of relief supplies. The use of welfare economics led Holguín-Veras et al. (2013) to suggest the use of minimization of social costs—the summation of the impacts of logistical decisions on all sectors of the society affected by the relief operation—as the objective function. Using social costs is important because the impacts on the beneficiaries cannot be assessed using private costs as the economic markets where supplies and services are normally traded are not likely to be functioning. Disasters could paralyze or destroy the local suppliers, the ability of sellers to bring goods to the market, or the ability of buyers to generate income to purchase goods or services. In such conditions, humanitarian aid becomes the only alternative. As a result, the impacts of the transactions involving relief supplies become externalities that must be captured in social costs (Varian, 1992; Holguín-Veras et al., 2013).

The implication is that proper HL modeling must ensure that the models account for the impacts of the delivery strategy on all involved. Three groups stand out among those impacted by a HL operation: the relief group itself; the individuals who receive aid at a given delivery-epoch; and the individuals who do not receive aid and must wait for future relief. In the social cost objective function defined in Holguín-Veras et al. (2013), the effects on these groups are measured in economic terms. The impacts on the relief group are the logistical costs associated with procuring, transporting, storing, and delivering the aid. The direct impact on the individuals who receive aid at a delivery-epoch is the reduction in their Deprivation Cost (DC)—the economic value of the deprivation of a good or service—brought about by the arrival of the supply or service. The computation of the impacts on beneficiaries necessitates translating the human suffering into a DC. It is also important to consider the impacts on the individuals who do not receive aid, because their DCs will increase as they wait for another delivery. These additional costs are the opportunity costs of the delivery strategy, which are important because in the days after a large disaster the supplies of critical items typically do not meet all demands. Thus, the number of individuals who do not receive relief aid typically outnumbers those who receive some. Sound HL decision-making boils down to judicious management of scarcity and human suffering. The use of welfare economics highlights the inadequacy of the proxy measures and approximate objective functions widely used in HL modeling (Holguín-Veras et al., 2013). At the same time, the use of social costs leads to models that, though computationally more complex, produce conceptually solid results. For instance, Pérez-Rodríguez and Holguín-Veras (2015) developed a social cost inventory-allocation model that produced compelling insight into the benefits of supply rationing. The mathematical models based on the alternative objective functions used in the literature are unable to reach such conclusions.

Although HL models based on social costs are a very promising approach, there are obstacles to their use. Foremost among them is the challenge of how to valuate, and incorporate into a social cost objective function, the human suffering produced by the deprivation of a critical supply or service. This is a complex undertaking that has to balance multiple considerations: accuracy and robustness of the valuations of deprivation, the level of difficulty associated with gathering the input data needed to estimate and use the resulting model, and mathematical tractability, among others. Methodological alternatives that perform the best in a single criterion are not necessarily the most appropriate for inclusion in a social cost model. In terms of assessment of the physiological impacts of deprivation, for instance, medical exams by well-trained physicians are the most precise mechanism to assess the health of individuals, in order to allocate resources to mitigate suffering. However, these assessments may not be practical in post-disaster environments where there are, lack of data about the impacted populations, and where rapid deployment of medical teams is difficult. Similarly, the most tractable metrics of human suffering, or the ones that use the least data, are not necessarily the most appropriate either because they may lead to formulations that cannot capture the complexities of the problem. The key is to identify a methodology that captures the essence of the phenomenon, and which requires data that could be readily obtained, and could lead to computable models. Adding to this already complex challenge, there are no publications that estimate anything that resembles DCFs.

The alternative considered in this paper uses Contingent Valuation techniques to collect stated preference data and econometrically estimate Deprivation Cost Functions (DCFs) that capture the DCs as a function of the Deprivation Time (DT). The proposed DCFs offer a good compromise solution. To start, they could be estimated using standard techniques of economic valuation and econometric modeling. Second, some of the inputs required to use these DCFs, e.g., number of individuals in the impacted areas, could be obtained from Geographic Information Systems (GIS), interviews with local responders, and the initial rapid-needs-assessments conducted by relief groups. Third, these DCFs can be readily incorporated into computable models, e.g., Pérez-Rodríguez and Holguín-Veras

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