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A micro foundation for discrete choice models with multiple categories of goods ☆

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ABSTRACT

Discrete choice models are well suited to describing consumer choice. However, conventional discrete choice models depart from standard utility maximization models in two important respects. First, in typical discrete choice models, the total demand for a choice set is exogenously fixed. Second, conventional discrete choice models have a limited ability to describe the unrestricted substitutionary or complementary relationships between multiple categories of goods. Both suggest that conventional discrete choice models correspond to a special utility maximization problem that we can develop to incorporate endogenous change in the total demand for a choice set and multiple categories of goods in an unrestrictive way. The purpose of this paper is to clarify the theoretical foundation of such discrete choice models in the context of standard deterministic utility maximization, derive the elasticities of the implied demand functions, and obtain a method for the calculation of welfare change. The framework in this paper is most useful for considering complementary relationships across categories, which is generally intractable in conventional discrete choice models in the absence of restrictive assumptions. The analysis demonstrates that the results of discrete choice models are perfectly consistent with standard deterministic utility maximization, even if the total demand for a choice set changes endogenously or with multiple categories of goods. Thus, discrete choice models are intrinsically more applicable across a much broader range of consumer choices.

1. Introduction

Discrete choice models are well suited to describing consumer choice. However, conventional discrete choice models differ from standard utility maximization models in two important respects. First, in typical discrete choice models, the total demand for a choice set is exogenously fixed, although standard utility maximization models are free from such restriction. For instance, consider the choice of soft drink brands A and B. In conventional discrete choice models, given the assumption that a consumer selects only one alternative, a consumer selects “brand A,” “brand B,” or “no purchase.” This model can certainly handle the change in the demand for each brand of soft drink, but provides no explanation as to why a consumer selects only one alternative, unlike a standard utility maximization model. In other words, the total demand for a choice set of brand A, brand B, and no purchase is exogenously fixed. This is a serious limitation of discrete choice models.

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Indeed, McFadden (1999, p. 273) and Nevo (2000, fn. 14, 2001, fn. 13, 2011) have repeatedly pointed out this limitation.[1] This problem is especially important given the application of discrete choice models to daily consumables, including ready-to-eat cereal (Nevo, 2001) and canned tuna (Nevo and Hatzitaskos, 2006), whose demand is more variable than that for durable goods such as housing (Earnhart, 2002) and automobiles (Berry et al., 1995, Goldberg, 1995, Petrin, 2002). The merit of using discrete choice models would probably outweigh this limitation in empirical estimation, but a theoretical justification is required.

Second, conventional discrete choice models have a limited ability to describe the unrestricted substitutionary or complementary relationships between multiple categories of goods, even though standard utility maximization models can intrinsically describe any relationship between goods. For example, while the nested logit model is capable of representing multiple categories of goods, the relationship between each pair of category is limited to the logit, that is, the assumption of a specific substitutionary relationship. In reality, substitutionary or complementary relationship between goods would be more complex. For example, soft drinks and potato chips may have a complementary relationship at least to some degree. Although there is allowance for complementarity in standard utility maximization models, as long as the budget constraint is satisfied, conventional discrete choice models have hitherto not provided a theoretical framework to include such a relationship.

The purpose of this paper is to develop a micro foundation for discrete choice models that incorporates endogenous change in the total demand for a choice set and unrestricted substitutionary or complementary relationships. For this purpose, we develop a standard deterministic utility maximization model. The reason we employ a standard deterministic utility maximization model rather than random utility maximization is so that we can directly observe the relationship between discrete choice models and the standard microeconomic framework, which is usually deterministic and without error terms. We further derive the elasticities of the implied demand functions and obtain a method for the calculation of welfare change to make the implications of the discrete choice models clear within the standard utility maximization framework.

The main results are as follows. First, as the simplest case, we begin by formulating a standard deterministic utility maximization model corresponding to the results of a simple logit model in which the demand for a category, which equals the total demand for a choice set, is endogenously determined. Our results here are a generalization of Anderson et al. (1988, 1992, Ch. 3) because the derived indirect utility function includes the indirect utility function implied by their analyses as a special case. The derived demand functions are consistent with the logit model, but the total demand for a category endogenously changes. We can then decompose the elasticities of the derived demand functions into the elasticity of demand for a category and the conventional elasticity of the logit model where the demand for a category is given. We demonstrate that including the former could make each alternative gross complements, whereas in standard discrete choice models, the relationship between alternatives is restricted to that of gross substitutes. We also derive a method for the calculation of welfare change, which is a generalization of Small and Rosen (1981), to incorporate a change in the demand for a category. We can then calculate a change in compensating variation using the log-sum term as the aggregated price of the demand for a category.

Second, we generalize our analysis to allow for multiple categories of goods. This analysis is novel in that we show that even if we consider multiple categories of goods, we can derive discrete choice models with endogenous change in category demand from standard deterministic utility maximization using a specific form of an indirect utility function. The elasticities of each category contribute to describing the complementary relationship between goods, and consequently, we can describe any substitutionary or complementary relationship between goods. This implies that any substitutionary or complementary relationship between goods in the results from the logit model is justified if we consider that the results derive from the corresponding deterministic utility maximization. We also extend the method for the calculation of welfare change to the case of multiple categories of goods using the log-sum term of each category as the aggregated price.

Third, our analysis extends to generalized extreme value (GEV) and mixed logit models. The implication of GEV and mixed logit models in the framework of standard microeconomic utility maximization with endogenous change in category demand is yet another of our new findings. Our analysis shows that we can derive the GEV model from standard deterministic utility maximization using only a slight modification of the analysis for the logit model. The mixed logit model arises by taking the expectation of the indirect utility function for the logit model. These results imply that we can consistently recognize the GEV and mixed logit models within the standard utility maximization framework.

Before proceeding, we briefly place our analysis in the literature. Using a deterministic utility maximization model, we provide a theoretical foundation for the logit, GEV, and mixed logit models in which the total demand for a choice set endogenously changes and multiple categories of goods can have unrestricted substitutionary or complementary relationships. The most related literature therefore concerns the theoretical foundation of discrete choice models from the viewpoint of a deterministic utility maximization framework. Our work also relates to product differentiation models within a deterministic utility maximization framework, which allows unrestricted substitutionary or complementary relationship

[1] Nevo (2001, fn. 13) states: “A comment is in place about the realism of the assumption that consumers choose no more than one brand. Many households buy more than one brand of cereal in each supermarket trip but most people consume only one brand of cereal at a time, which is the relevant fact for this modeling assumption. Nevertheless, if one is still unwilling to accept that this is a negligible phenomenon, this model can be viewed as an approximation to the true choice model.” Nevo (2000, fn. 14, 2011) makes a similar point. McFadden (1999, p. 273) likewise raises the possibility that an alternative can be interpreted “…as a ‘portfolio’ of decisions made in sequence, or as one of the multiple decisions”.