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Linking discrete choice to continuous demand within the framework of a computable general equilibrium model

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ABSTRACT

Discrete choice (DC) models are commonly used as basic building blocks in 'bottom-up' models which seek to describe consumer and producer behaviour at a disaggregate level, in contrast to continuous demand (CD) models which are used to describe behaviour at a more aggregate level. At a disaggregate level, choice behaviour is defined in terms of commodities differentiated by qualities or attributes. In contrast, aggregate demand behaviour is defined in terms of broadly defined and generically different commodities. In a DC model, the main focus of analysis is not the total quantity of demand, but rather the relative shares or substitution between the choice alternatives, in contrast to a continuous demand model where the focus is on the aggregate substitution between groups of commodities as well as on the income effects. Seen in this way, there is scope for complementary usage of DC and CD models within the framework of a CGE model where DC models are used to describe the preferences for a narrowly defined set of commodities belonging to a particular sector of an economy, and CD models are used to describe the interactions between these sectors. In this paper, we describe how DC and CD models can be used in such an integrated fashion in a spatial computable general equilibrium model to inquire into the wider economic impacts of a transport investment project in the Sydney Metropolitan Area.

1. Introduction

Discrete choice (DC) models are often used as the basic building blocks in a bottom-up model which seeks to describe consumer and producer behaviour at a disaggregate level. Such models are often rich in details of the choice alternatives, as well as characteristics of the individual decision makers, and therefore can capture the behavioural responses of individuals to economic policies more accurately than can aggregate models of supply or demand. For example, the decision on commuter mode choice in a DC model can be described not only in terms of the attributes of the travel modes (travel time, travel cost, comfort level, convenience, etc.), but also the socio-economic characteristics of each decision maker (income level, age-group, position in family structure, occupation, flexibility of travel time, etc.). Similarly, the decision on workplace or residential location in a DC model can be described in terms of the varied economic characteristics of the location (e.g., average wage paid for a particular type of work in that location, average rental cost for different housing types, transport costs between different origin and destinations, etc.). This means that policies which seek to influence decisions at the disaggregate level on mode choice or locational choice can be more accurately analysed if set within the framework of a disaggregate DC model.

At a disaggregate level of choice decision, however, the typical choice set within a DC model often consists of mainly a narrowly-defined set of varieties, or alternatives, of a particular commodity e.g., different modes of travel, different types

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of cars. These varieties or alternatives are differentiated mainly by quality attributes rather than simply by market prices (which can be considered as the summary indices for these attributes).[1] In contrast, continuous demand (CD) models which look at behaviour at a more aggregate level are concerned only with the demand for groups of commodities which are generically different (transport, food, housing, education, health, etc.). These groups are to be 'differentiated' only or mainly via their market prices.[2] The choice decision within a DC model is therefore concerned primarily with the 'fine' substitution between different alternatives or varieties of a particular commodity (often produced within a particular sector of an economy), rather than with the gross substitution between groups of commodities (belonging to different sectors of an economy) and the effect of income or budget level on their demand. Seen in this way, there is scope for complementary[3] usage of DC and CD models within the framework of a CGE model, where DC models can be used to describe the preferences for a narrowly defined set of commodities, while CD models are used to describe the interactions between the demands for different groups of commodities.

In this paper, we describe how DC and CD models can be used in such an integrated fashion in a spatial computable general equilibrium model to inquire into the wider economy impacts of a transport investment project. These wider impacts are to be considered *in addition to* the usual impacts on the users of the transport network as considered in traditional (partial) benefit-cost analysis (Graham (2007a,b). In the past, there have been studies which also looked at the issue of using a DC model within the framework of a CGE framework (see for example, Horridge (1994)). However, the approach so far has been limited to the use of a theoretical functional form (such as the linear logit[4]) in a CGE model to replace the use of other alternative functional forms (such as CES) to describe demand for different varieties of a particular activity or commodity (such as transport mode choice or location choice). It has not been extended to the use of an *actual* or *true* DC model in a CGE framework. Here we can define a 'true' DC model as one specified and estimated using *individual-specific discrete choice data* rather than estimated (or calibrated) using only aggregate or average market share data (as is the case of the linear logit model). The use of such a model in a CGE framework presents both challenges as well as potential advantages which will be explained in this paper.

The plan of the paper is as follows. Section 2 introduces the Multinomial Logit (MNL) discrete choice model as the basic structure used in most disaggregate behavioural models of choice behaviour. Sections 3 and 4 explain how a MNL basic structure can be considered as part of a (conditional) demand system for simple and more complex decision structures. Section 5 then illustrates the connection between DC and CD models within a CGE framework, with an empirical example taken from a study of the wider economic impacts of an urban transport investment project, and Section 6 gives some conclusions.

2. Multinomial Logit (MNL) discrete choice model

A typical MNL model of discrete choice is specified as follows:

$$Prob_i = \frac{\exp(V_i)}{\sum_{j\in I}\exp(V_j)}; \quad i \in I. \tag{1}$$

$Prob_i$ is the probability of alternative i being chosen from a choice set I, and V_i is the (indirect) utility function of the choice alternative i. The indirect utility function V_i is usually specified as a linear function of all the *attributes* of the choice alternative as well as the *characteristics* of the individual who chooses this alternative[5]:

$$V_i = \sum_{m\in M}\alpha_m A_{im} + \sum_{n\in N}\beta_n B_{in}, \quad i \in I. \tag{2}$$

A_{im} stands for the attribute m of alternative i, B_{in} is the characteristic n of the individual who chooses alternative i; and α_m and β_n are parameters.[6] For example, if i is a mode choice alternative (say "bus") then A_{im} can be variables describing the travel time

[1] Using the Lancaster approach to consumer demand based on commodity characteristics or attributes (Lancaster, 1966). Discrete choice models therefore are often used for the study of the demand for quality-differentiated products. See for example Berry, 1994; Berry et al., 1995, 2004.

[2] Market price is also often used in a DC model but this plays the role of only one particular attribute among many, while in a continuous demand model it is the main (and often only) 'attribute'.

[3] An alternative approach is to use a DC model in a 'conditional demand' mode and then trying to relate the choice elasticities to demand elasticities (see, for example, Smith et al., 2010). Although this approach is not inconsistent with our approach (see, for example, Section 3.2 below), it tends to restrict the usefulness of a DC model because it implies that DC and CD models are merely *substitutes* which can be used to analyse the same problem, while in fact, DC and CD models are quite fundamentally different and designed to deal with different issues. For example, a CD model is not well designed to handle the issue of consumer heterogeneity or product variety, but strong in dealing with the issue of income and relative price effects. The reverse is true for DC models. Therefore DC and CD are more complements rather than substitutes.

[4] That is, a logit model of choice behaviour which is specified and estimated using market shares data rather than discrete individual choice data (see Oum, 1979).

[5] Although product variety and consumer heterogeneity can be considered as equivalent from a theoretical viewpoint, if we look only at the aggregate (or average) behaviour of a 'representative' consumer, and if the distribution of the heterogeneous consumer preferences can described in terms of symmetrical positions in the attribute space with respect to the various choice alternatives (product varieties) (see for example, Anderson et al., 1988b, 1989), it is still convenient to distinguish between these two concepts from an empirical point of view because in practice, a DC model describes 'consumer heterogeneity' in terms of the characteristics of the decision maker, while product variety is specified in terms of the attributes of the choice alternatives. Developments such as mixed logit however allow for heterogeneity on the attributes.

[6] In general, the parameters α_m and β_n are assumed to be 'generic', i.e., independent of the choice alternatives, except for the parameter of the constant term, which can be assumed to be 'alternative-specific', and this parameter can be represented by the symbol l_{i0} where $\alpha_{i0} \neq \alpha_{j0}$ for $i \neq j$.