A copula-based joint multinomial discrete-ordered model of commuting mode choice and number of non-work stops during the commute

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Abstract
Mode choice has traditionally played a central role in transportation modelling research and applications. In fact, the behavioural process underlying travel mode choice is a critical determinant of the effectiveness of policies designed to shift travel from the solo-auto mode to high-occupancy vehicle modes. In this behavioural process context, the last decade has seen the increasing use of tours (or sequences of trips from home-to-home or work-to-work for mid-day periods) as the unit of analysis for travel choice dimensions. Such a tour-based approach preserves the consistency and integrity of destination, mode, and time of day choices across trips within the same sojourn from home (or from work for mid-day stops).

In this paper, in the spirit of a tour-based frame of analysis, we examine commute mode choice and the number of non-work stops during the commute (in this abstract, "commute" will refer to travel between the home and either the work place for workers or the school place for students; also, we will use the term "work" to include "school" for students). Understanding the mode and activity stop dimensions of weekday commute travel is important since the highest level of weekday traffic congestion in urban areas occurs during the commute periods. This is particularly so because of the increasing number of non-work stops for leisure and maintenance purposes that are being pursued during the commute trip (especially the evening return-home trip). On the other hand, almost all earlier studies ignore the joint nature of the commute mode and number of non-work stops decisions. In particular, while some earlier studies consider mode choice as an exogenous determinant of the number of stops during the commute, others consider the number of commute stops as an exogenous determinant of commute mode choice.

The paper employs a copula-based joint multinomial logit - ordered modelling framework in which commute mode choice is modelled using a multinomial logit model and the number of commute stops is modelled using an ordered response formulation. The copula-based methodology facilitates model estimation without imposing restrictive distribution assumptions on the dependency structures between the errors in the discrete unordered and ordered choice components. Specifically, the copula approach allows one to test several different parametric dependency structures for the joint distribution of the error terms in the two equations (as opposed to the usual joint normal distribution used de facto in earlier studies). The copula concept has been recognized in the statistics field for several decades now, but it is only recently that it has been explicitly recognized and employed in the econometrics field. It is simple to implement and does not restrict the analyst from using rich and comprehensive variable specifications, as does a non-parametric dependency formulation.

The data used in this study are drawn from the "Time use" multipurpose survey conducted between 2002 and 2003 by the Turin Town Council and the Italian National Institute of Statistics (ISTAT) in the Greater Turin metropolitan area of Italy. A total of 1830 households responded to the survey, comprising an individual sample size of 4500 individuals. The estimation sample of individuals employed in this work includes active individuals aged 14 and over (workers or students) who are able to use at least one motorized mode (i.e. moped, scooter, motorcycle, car etc.). An individual is classified as a
worker or student if, on the survey day, he/she engaged in at least one work or study trip. The final sample size of individuals used in the current analysis is 957.

The analysis will evaluate a variety of copula structures to capture the dependency between commute mode choice and number of non-work commute stops, based on data-fit measures and intuitive considerations. To our knowledge, this research constitutes the first formulation and application of a copula-based sample selection model for the case of a multinomial unordered response selection criterion with an ordered-response outcome. A number of policy scenarios will be simulated using the different copula models to highlight the potentially biased forecasts that can result from using the incorrect dependency structure or from assuming independence between commute mode choice and the number of commute activity stops decisions.