Nonmotorized Transport Choice Model and the Effect of Lower Bus Fares on Different Income Groups

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Government expenditures in the transport sector are usually discussed as though they were neutral with respect to the benefits they provide to various income groups. A choice model for alternative transport modes, including nonmotorized vehicles, is presented, with emphasis on the relationship between income levels and relative prices. The derivation of the model, based on individual preferences, is described in detail, and its application to aggregate data is made explicit. The application is for passenger trips to work in four cities in Indonesia in the early 1980s. The scenario whereby the government intervenes in the provision of public transport services, for example, by subsidizing bus fares, is simulated, and shows the sensitivity of each income group, in the short run, to such an exogenous shock.

Government expenditures in the transport sector are usually discussed as though they were neutral with respect to the benefits they provide to various income groups. The purpose of this paper is to provide an analysis of the demand for alternative transport modes, including nonmotorized vehicles and walking, with particular emphasis on the relationship between income levels and relative prices. The theoretical framework consists of a choice model based on individual preferences, and the application is for passenger trips to work in four cities in Indonesia in the early 1980s. The focus of the analysis is on policies that may affect relative prices, such as government intervention in the provision of public transport services. If bus companies are subsidized to provide cheaper services, will the demand for other low-cost modes and services decrease? How will the effect vary by different income groups?

THEORETICAL FRAMEWORK

Although choice probabilities can be defined for individuals, a series of choice situations for single individuals is seldom observed. Rather, the choices made by some set of individuals, such as the proportion of people choosing an alternative over an entire sample population, are usually observed. The objective of this paper is to analyze modal shares by income groups, such as the share of bus trips taken by individuals in a high-income group relative to the bicycle trips taken by individuals in a low-income group. Since few surveys exist on mode choice for individuals (stratified by income groups), it is difficult to estimate a model based on these individual shares.

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However, if we assume that the individuals observed to choose alternative modes are independent random samples from the total population, the proportions by income groups can be written as a conditional probability based on the total shares. That is,

$$P_i = \sum_{g \in G} P_g P(i|g) \tag{1}$$

where

P_i = probability that a randomly observed trip is by Mode i,
P_g = probability that a randomly sampled trip maker is in Group g, and
$P(i|g)$ = probability that a randomly observed trip is by Mode i given that the trip maker is in Group g.

If we assume a functional form for the choice probabilities of the individuals in the income groups, $P(i|g)$, and assume that the probability of a randomly observed trip maker belonging to Group g is proportional to the population in Group g, a model in which the P_i's are observed can be estimated on the basis of the trip maker's indirect utility function. This indirect utility is described in more detail below. Let

$$Y_{in} = Y(W_n, C_i)$$

be the indirect utility function for Individual n choosing Alternative i, where W_n is the wage level of Individual n and C_i is the cost of Alternative i.

The indirect utilities used in this paper have been derived from individual preferences regarding various combinations of goods and leisure, subject to budget and time constraints. Their derivation is given elsewhere (*1*, pp. 24–26).

Assume that Y_{in} consists of a systematic component that is observable, V_{in}, and an idiosyncratic component, e_{in}, that is not observable. Assume also that we do not observe variation across individuals' systematic components or variation of choice sets within the same income group. More formally,

$$n, n' \in g \Rightarrow V_{in} = V_{in'} \equiv V_{ig} \quad \text{and} \quad C_n = C_{n'} \equiv C_g$$

Hence all individual variation is in the (unobserved) idiosyncratic component, and we can rewrite the indirect utility as follows:

$$Y_{in} = V_{ig} + \varepsilon_{in} \qquad \forall\, n \in g, \quad i \in C_g \tag{2}$$

The conditional probability that a randomly observed trip is by Mode i, given that Individual n is in Group g, is then given by

$$P_{i|g} = Pr(Y_{in} \geq Y_{jn} \quad \forall j \in C_g, j \neq i)$$
$$= Pr(V_{ig} + \varepsilon_{in} \geq V_{jg} + \varepsilon_{jn} \quad \forall j \in C_g, j \neq i) \quad (3)$$

If we now make an assumption regarding the random components e_{in}, namely, that they are identically and independently distributed with the extreme value distribution (*2*, p. 53), the probabilities can be written as a logit function:

$$P(i|g) = \frac{\exp(V_{ig})}{\sum_{j \in C_g} \exp(V_{jg})} \quad (4)$$

Recalling that we do not observe $P(i|g)$ but that we do observe P_i, the total number of people choosing Mode i from the population, we need one more assumption to estimate the model: each individual is equally likely to be the observed trip maker. That is,

$$P_g = \frac{M_g}{M} \quad (5)$$

where M_g is the population of Group g and $M = \Sigma_g M_G$.

Substituting Equations 4 and 5 into Equation 1, the observed proportion of the population choosing Alternative i can be written as

$$P_i = \sum_g \frac{M_g}{M} P(i|g) \Rightarrow P_i(\beta) = \sum_g \frac{M_g}{M} \frac{\exp(V_{ig})}{\sum_{j \in C_g} \exp(V_{jg})} \quad (6)$$

where V_{ig} is the observable component in the trip maker's indirect utility function.

THE INDIRECT UTILITY FUNCTION

The indirect utility function (Y_{in}) that is estimated in this paper attempts to capture the effects of cost (c) relative to income (W). Recall that it consists of a systematic component (V_{ig}) and an idiosyncratic component (e_{in}).

$$Y_{in} = \beta_i - \beta_g\left(\frac{C_i}{W_g}\right) + \varepsilon_{in} \quad (7)$$

The indirect utility includes a constant or intercept term, β_i, for each mode, which mitigates to some extent the independence of irrelevant alternatives (IIA) underlying logit models. Train gives an example of the IIA property and the function of the mode-specific term (*2*, pp. 22–23). Variations on the functional form above, including ones with time of travel and an estimated loss in wages variable, were also estimated but are reported elsewhere (*1*). This one was chosen because its estimated coefficients are the most significant and because it clearly illustrates the differences in the demand elasticities by income groups, discussed in the next sections.

APPLICATION

The estimates are based on aggregate data and are for work trips in four Indonesian cities, where it has been possible to approximate incomes of users and relative costs and attributes of a handful of nonmotorized and motorized modes. The intent is to illustrate how mode choice estimates stratified by incomes can be obtained from such data and how simulation of the effects of changes on various groups might be calibrated with more detailed surveys.

The data have been compiled from Leinbach and Sien (*3*, Tables 8.5, 8.6, and 8.7) and from other sources available from the author. The four cities are Jakarta, Surabaya, Bandung, and Yogyakarta during the period 1978 to 1982. The data reflect the choice of six possible modes: automobile, bicycle, bus, motorcycle, pedal trishaws or becaks, and walking. The estimated populations were 6.41 million for Jakarta, 2.3 million for Surabaya, 1.4 million for Bandung, and 0.36 million for Yogyakarta.

Becaks are pedal-driven tricycles that carry two or three passengers and can also carry goods or luggage. Becaks and nonmotorized modes make up a large proportion of the vehicles owned in Indonesia. In Yogyakarta, nonmotorized modes made up 52 percent of the total registered vehicles. Motorcycles accounted for another 33 percent of the vehicles in 1974 (*4*, p. 28). The bus category includes minibuses and jitneys, all following a fixed route. The jitneys are remodeled automobiles, such as the Colt, Honda, or Opelet, and usually carry up to 17 passengers. A third type of public transport, the bemo or motorized becak, is also used in some areas, but the percentage of bemos was not available for most of the cities and was allocated partially to the bus category and partially to the becak category in the case of Jakarta.

The observed data given in Table 1 are the proportion of people who choose each of the six modes for their trips to work, assuming only one mode is chosen.

The cost (c_i) per day is an unweighted national average of the final purchase price of either the vehicle or the transport service. Strictly speaking, the cost of walking should be valued as lost wages due to travel time, but for this paper, specifications using travel time have not been included. Assigning zero cost to walking is equivalent to assigning all the relative utility of the mode to the constant (or intercept term). Instead, by choosing a nonzero cost for walking, we allow the constant to capture other unobserved utilities and the cost parameter to reflect the effect of a very low-priced mode. Thus, the cost of walking was assigned an almost negligible value, roughly equal to the price of a pair of shoes, or U.S. $10 per year at real prices. Although the estimates used here are reasoned but very rough ones, they are consistent with independent estimates based on a detailed cost study for the entire Yogyakarta province (*5*, p. 17).

The proportion of people in each income group (M_g/M) is based on the average income level of Indonesia relative to the world average income level and the Gini coefficient of income distribution. Approximately 67 percent of the popu-

TABLE 1 Proportion (P_i) of People Choosing Each Mode (percent)

P_i (%)	Auto	Motor Cycle	Bus	Becak	Bicycle	Walking
Bandung	5.8	17.3	17.7	9.7	5.6	43.9
Jakarta	12.0	8.0	23.7	3.2	1.1	52.0
Surabaya	7.5	21.0	17.5	9.5	9.5	35.0
Yogyakarta	2.2	15.2	10.5	3.4	23.2	44.6
Cost rps/day	1553	332	74	34	25	12

lation earn less than two-thirds of the world average income level, 22 percent earn between two-thirds and four-thirds of the average, and 11 percent earn more than four-thirds of the world average income level. A description of the income distribution estimates is given elsewhere (*1*,*6*). The world average income, equal to $3,768 in 1985, was calculated on the basis of real gross domestic product per capita in 1985 prices for approximately 130 countries (*7*). In addition to the proportion of people in each income group, the actual income levels in each group (W_g), expressed in national currency units (rupiahs), are as follows: low, 1,252; middle, 3,755; high 6,258.

The exchange rate in 1980 was 627 rupiahs per U.S. dollar, and the purchasing power (PPP) of the rupiah relative to the dollar was 45 percent of the exchange rate (285 rupiahs per U.S. dollar). This means that a basket of goods costing U.S. $1.00 in the United States could be purchased for U.S. $0.45 in Indonesia. The relative prices and income levels used in this paper have been converted using the PPP rather than the exchange rate, since this is more appropriate for international comparisons.

RESULTS

This section discusses the results of the estimated choice model and the demand elasticities by income groups.

$$P_i(\beta) = \sum_g \frac{M_g}{M} \frac{\exp\left[\beta_i + \beta_g\left(\frac{C_i}{W_g}\right)\right]}{\sum_{j\in C_g} \exp\left[\beta_j + \beta_g\left(\frac{C_j}{W_g}\right)\right]} \quad (8)$$

The maximum likelihood estimates of the coefficients are presented in Table 2.

Recall that the mode-specific constants capture the average effect of each mode relative to walking (the base mode). It is high and positive for the motorized modes (automobiles and motorcycles) and negative for bicycles. The coefficient on the (cost/wage) variable is negative, as expected, and also significant.

If bus companies are subsidized and fares decrease substantially, will the demand for services vary by different income groups? The arguments against subsidies are that the poorest people cannot afford to use public transport even when it is subsidized and that subsidizing transport makes the geographical areas that it serves attractive to large businesses. These arguments imply that subsidies are not effective as transfer payments to the poor. It has also been argued that government regulation and subsidies would reduce the demand for paratransit, or intermediate transport modes that are often informal and unregulated but numerous in many South Asian cities. One of the ways to model such questions is to simulate changes in parameters and to estimate the proportional change in demand, thus showing the short-run effect of an exogenous shock to the system.

TABLE 2 Estimated Coefficients and Standard Errors

Observations=24	Coefficient (Std.error)
Auto	58.88 (13.01)
Motorcycle	22.89 (4.40)
Bus	6.59 (1.60)
Becak	0.68 (0.55)
Bicycle	-0.51 (0.92)
Cost/Wage	-61.40 (14.94)
SSE	0.0568

The estimated coefficients shown in the previous section allow us to calculate the proportion of users in each income group $P(i|g)$ on the basis of the cost, time, and income variables. That is,

$$P(i|g) = \frac{\exp\left[\beta_i + \beta_g\left(\frac{C_i}{W_g}\right)\right]}{\sum_{j\in C_g} \exp\left[\beta_j + \beta_g\left(\frac{C_j}{W_g}\right)\right]}$$

If we now assume that there is an exogenous shock to the system, such as the subsidized decrease in bus fares discussed above, the proportions $[P(i|g)]$ can be estimated a second time with the new fares. The difference between the new, simulated proportions and the original proportions, expressed as a percentage of the original ones, is equal to the expected change in demand by income groups, or elasticities of demand.

The cost of the average bus fares was decreased by 25 percent simulating the scenario whereby the government subsidizes bus services. The increase in demand for low-, middle-, and high-income groups was 56, 21, and 16 percent, respectively. This suggests that the low-income groups are more sensitive to changes in fares than the middle- and high-income groups.

Clearly, the elasticities vary by income group and are higher than unity for the poorest group. Similarly, the effect of an increase in fares would decrease the demand for public bus services proportionally more in the lowest-income group. Given that in this analysis only the nonmotorized modes are cheaper than buses, the low-income groups would switch to pedal trishaws (or becaks), bicycles, and walking.

CONCLUSIONS

Although there are several data constraints on the estimated models and the models themselves are limited to simple assumptions about individual behavior, the results show how changes in relative prices of modes have a varying effect on different income groups and how the demand for alternative modes is not necessarily neutral across income levels. Thus, although it may be argued that subsidies are not always effective as transfer payments to the poor, especially in the case of marketable goods, it may be useful for transportation planners to analyze the use of subsidies in the provision of both motorized and nonmotorized bus services. They are less likely than goods to be transferred and can thus be more effectively targeted to the low-income groups. This is especially relevant in developing countries where informal transport services are an essential component in urban transport services and where there are potential benefits to investors and lending organizations in analyzing the more modest infrastructure requirements for nonmotorized vehicles and transport services.

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