Choice Model of Employee Participation in Telecommuting Under a Cost-Neutral Scenario

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A multinomial logit model was constructed of employee participation in telecommuting using stated preference data extracted from a survey of employees of information-oriented firms in Austin, Dallas, and Houston, Texas. Respondents were given work site alternatives in a scenario in which all telecommuting costs were incurred by the employer. Explanatory factors in the employee's decision are identified, including travel, work, and socioeconomic variables. Maximum likelihood estimation results were calculated for a pooled model and for the individual cities. Understanding the characteristics of willful telecommuters lends insight into the likely makeup of the future telecommuting population and, subsequently, the impact on transportation systems.

Friction-reducing telecommunications technologies have given rise in the last decade to a new work arrangement defined in the transportation literature as telecommuting. In general, telecommuting refers to the replacement or reduction of the daily commute by working from home or from a regional work center, usually aided by telecommunications or computing equipment. Of course, home work has existed throughout history; its current significance to the transportation field lies in its potential as a travel demand reduction strategy. Since the early 1960s researchers have touted the potential benefits of telecommuting associated with mitigated peak-hour congestion, such as reductions in travel times, fuel consumption, air pollution, and public capital investment in transportation (*1,2*). These early papers focused on telecommunications as a potential substitute for travel. The instability of oil prices in the early 1980s stimulated a body of theoretical research on the social, organizational, technical, and behavioral aspects of telecommuting (*3–6*). This work broadened the scope of telecommuting's impact to include substitutive, complementary, altering, and intensifying effects on travel.

In recent years, attempts have been made to underscore potential benefits to individual telecommuters in terms of lower commute costs, greater schedule flexibility, and a more comfortable work environment (*7*). In addition, it has been speculated that employers of telecommuters may acquire competitive advantages in hiring, office overhead cost savings, and productivity gains. At the same time, potential drawbacks to both workers and managers have been identified. Some of the more commonly discussed disadvantages to telecommuters include professional and social isolation, absence of support services, increased household costs, and the potential for management exploitation. Meanwhile, there is reason to believe that employers of telecommuters might incur relatively high program startup costs, management reluctance with regard to remote supervision, and problems with data security. Identifying significant barriers is crucial to understanding why telecommuting has not become more widespread given the extensive availability of the enabling telecommunications technologies.

Telecommuting has entered public policy rhetoric in California, Washington, Florida, and Virginia as a means of achieving trip reductions at the firm level (*8*). In addition to pilot programs in these states, several examples exist of telecommuting programs organized and maintained in absence of government intervention (*9,10*). Published performance reviews have been overwhelmingly positive. The actual amount of telecommuting currently taking place has been difficult to pinpoint due to uncertainties about definitions in reference to available data (*11,12*).

Clearly the impact of telecommuting on transportation systems in the future hinges on the rate at which telecommuting is adopted as a work arrangement. A disaggregate choice model was constructed of the decision to participate in a hypothetical cost-neutral telecommuting program offered to employees of information-related firms in Austin, Dallas, and Houston, Texas. Employees were surveyed in an attempt to elicit information about their attitudes and stated preferences toward working from home. Ultimately, this model of employee participation will be applied along with an analogous model of employer provision to forecast the amount of telecommuting to expect in the next few decades, characteristics of the telecommuting population, and the impact on transportation systems.

A conceptual framework demonstrating the problem methodology is presented, followed by a brief description of the survey design and relevant respondent summary statistics, a discussion of the model specification and estimation results, and concluding remarks.

CONCEPTUAL FRAMEWORK

The theoretical background for this analysis can be summarized in Figures 1 and 2. On the macrolevel, Figure 1 presents a framework for analyzing the impact of telecommuting on transportation systems. Figure 2 outlines the individual decision processes of firms and employees that determine the total amount of telecommuting that occurs.

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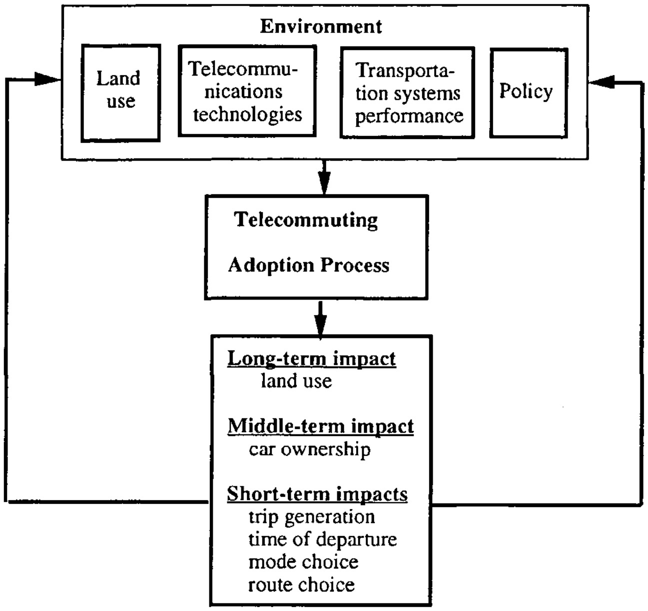

FIGURE 1 Interactions of telecommuting adoption process and the environment.

Figure 1 indicates environmental factors that influence individual participation decisions, including transportation system performance, supply of telecommunications technologies, area land use patterns, labor market conditions, and public policy with respect to telecommuting as a travel demand management strategy. The sum output of these individual decisions has short, medium, and long-term effects on travel, as shown in the figure. Telecommuting has an immediate impact on trip-making in terms of frequency, mode choice, and distribution over time and space. Eventually, telecommuting influences decisions on automobile ownership, residential location, and firm location, creating feedback effects on the environment and travel behavior. In this respect, telecommunications and transportation interactions extend beyond the work commute to affect shopping and recreational travel.

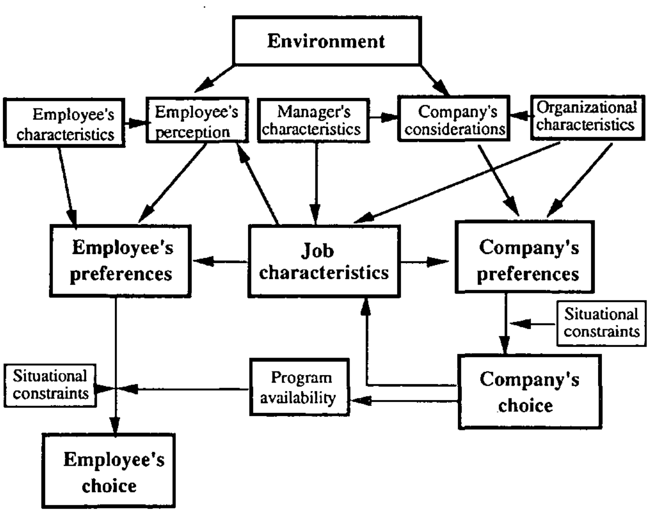

FIGURE 2 Telecommuting adoption process.

This paper is concerned with identifying prevailing factors in the employee decision whether to telecommute. This decision process is illustrated in Figure 2 along with the organization's decision whether to offer a telecommuting option. In a given environment, characteristics of employee, management, the firm, and jobs within the firm determine the attitudes and preferences concerning telecommuting. The employee is constrained by the firm's higher-order decision on program availability. Collective individual decisions produce the level of adoption represented by the central box in Figure 1 which generates the travel impacts.

SURVEY

The employee survey has four parts. The first section contains a set of questions concerning general job characteristics, commuting habits, and communication activities at work. The second part is composed of inquiries into attitudes toward commuting, work in general, and work at home. The next set of questions asks the respondent to select a work arrangement from a choice set consisting of various degrees of home telecommuting given a particular scenario of telecommuting cost allocation and salary. The final group of questions extracts socioeconomic information and computer skill levels. A detailed description of the survey and an exploratory analysis of the responses are presented by Mahmassani et al. in another paper in this Record. Table 1 presents summary statistics on the characteristics of the survey respondents for the relevant independent variables.

The scenarios extended four home telecommuting alternatives: (a) yes, work from home every day (full-time); (b) yes, work from home several days per week (part-time); (c) possibly; and (d) no. The choice model calibrated here is derived from responses to an all-else-equal scenario, one in which all costs of telecommuting are incurred by the firm. The distribution of responses is shown in Table 2 for each city, with corresponding percentages in parentheses.

MODEL SPECIFICATION AND ESTIMATION RESULTS

Model Form and Specification

The employee's decision to participate in a telecommuting program with the characteristics described earlier is modeled as a choice among four discrete alternatives, corresponding to the four possible responses to the question. The intent is to relate the employee's stated preferences toward telecommuting to the factors highlighted in Figure 2, namely the employee's individual and household characteristics, work and work-related attributes, as well as travel-related variables. This is accomplished by formulating and calibrating a multinomial logit model that relates the discrete response variable to a set of explanatory variables. To derive the specification and interpret the model, the response can be viewed as resulting from the relative magnitudes of four continuous latent variables (corresponding to each alternative, respectively) U_{in},

TABLE 1 Characteristics of Survey Respondents

Travel Variable	Mean	Standard Deviation
round-trip commute time t; 0 if t≤20, t if 20<t<80, 80 if t ≥80	48.27	25.73
commute stops per week	5.17	4.57

Work Variable	One	Zero
length of time with firm s; 1 if s ≥5 years, 0 otherwise	201	461
avg. time using computer per day c; 1 if c >4 hours, 0 otherwise	379	283
face-to-face communication f; 1 if response is several times per day with any group, 0 otherwise	566	96
work end time e; 1 if e > 5:30 P.M., 0 otherwise	329	333

Socio-economic Variable	One	Zero
females w/ children; 1 if yes, 0 otherwise	116	546
males' household income y; 1 if y<$25,000 annually, 0 otherwise	19	643
gender; 1 if female, 0 if male	366	296
age a; 1 if a ≥50 years old, 0 otherwise	46	616
marital status; 1 if married, 0 otherwise	390	272

$i = 1, 2, 3, 4$, $n = 1, \ldots N$, reflecting employee n's preferences for a given option i. Each latent variable consists of a systematic component and a random component. The former captures the systematic effects from the observable factors mentioned previously. The latter captures unobservables. By assuming that the employee's response corresponds to the latent variable with the maximum value in the choice set, and that the random components are identically and independently Gumbel distributed across the observations, the probability that individual n chooses alternative i is given by the usual multinomial logit model form:

$$P_n(i) = \frac{e^{\beta X_{in}}}{\sum_{j \in C_n} e^{\beta X_{jn}}}$$

where

C_n = choice set,
βX_{in} = systematic component of alternative i with β a vector of coefficients to be estimated, and
X_{in} = vector of explanatory variables.

TABLE 2 Distribution of Responses: Cost-Neutral Scenario

City	Full-time	Part-time	Possibly	No
Austin	63 (18.2%)	160 (46.2%)	84 (24.3%)	39 (11.3%)
Dallas	43 (24.9%)	72 (41.6%)	35 (20.2%)	23 (13.3%)
Houston	36 (25.2%)	62 (43.4%)	30 (21.0%)	15 (10.5%)
Total	142 (21.5%)	294 (44.4%)	149 (22.5%)	77 (11.6%)

Estimation Results

Table 3 presents the maximum-likelihood parameter estimates and corresponding *t*-statistics for the pooled (over the three cities) employee choice model, calculated using SST software (*13*). The "no" response has been scaled to zero. As noted earlier, the explanatory variables can be grouped into three categories: travel related, job related, and socioeconomic.

The two travel-related variables included in the model are (a) round-trip commute time and (b) average number of stops per week linked to the commute. The model reveals an inclination toward full-time home telecommuting associated with longer work commute times. The travel time variable (t) is defined as zero up to a round-trip commute time of 20 min; t equals actual travel time through 80 min, after which t equals 80. The empirically determined truncation is consistent with earlier findings (*14*). This desirable result implies that reductions in vehicle-miles traveled, fuel consumed, and pollutants emitted due to the absence of a telecommuter from an urban network will be greater relative to the average commuter. Also, the average number of stops per week along the work commute is positively related to both full-time and part-time alternatives. Presumably an individual reporting frequent stops along the work commute is predisposed toward telecommuting so as to enjoy greater schedule flexibility.

Four job-related variables appear in the model. All take the form of one-or-zero dummy variables. A length of service variable (s) equals 1 if the commuter has been employed by the same firm for 5 years or more. It is negatively related to both the full-time and part-time alternatives. It could be that employees who have maintained the same employer for 5 years or longer are relatively more comfortable with their jobs and with their office worksite. These employees would be less anxious to experiment with alternatives, particularly if they are in management-track positions.

A computer use variable (c) equals 1 where the employee spends at least 4 hr per day working at a computer. As expected, it is positively related both to the full-time and part-time alternatives. This variable is of particular interest to forecasting. As more jobs become computer-task-oriented and workers become more knowledgeable about and comfortable with using computers, more workers are expected to become interested in home telecommuting, according to the model.

The communication variable (f) equals 1 if the respondent experiences several instances per day of face-to-face communication with either supervisors, coworkers, subordinates,

TABLE 3 Parameter Estimation Results for Pooled Model

Independent Variable	Full-time	Part-time	Possibly
constant	-0.49 (-1.20)	0.18 (0.71)	0.46 (1.69)
round-trip commute time t; 0 if t≤20, t if 20 <t<80, 80 if t ≥80	0.013 (3.04)		
commute stops per week	0.058 (2.66)	0.058 (2.66)	
length of time with firm s; 1 if s ≥5 years, 0 otherwise	-0.58 (-3.08)	-0.58 (-3.08)	
avg. time using computer per day c; 1 if c >4 hours, 0 otherwise	0.80 (4.58)	0.80 (4.58)	
face-to-face communication f; 1 if response is several times per day with any group, 0 otherwise	-0.54 (-2.10)		
work end time e; 1 if e > 5:30 P.M., 0 otherwise	-0.76 (-3.70)		
females w/ children; 1 if yes, 0 otherwise	0.86 (2.72)	0.86 (2.72)	
males' household income y; 1 if y<$25,000 annually, 0 otherwise	1.08 (2.16)		
gender; 1 if female, 0 if male	0.34 (1.79)	0.34 (1.79)	
age a; 1 if a ≥50 years old, 0 otherwise		-0.59 (-1.86)	-0.59 (-1.86)
marital status; 1 if married, 0 otherwise	0.76 (3.00)	0.76 (3.00)	0.76 (3.00)
Number of Observations	662		
Log-likelihood at zero	-917.73	ρ^2=0.147	
Log-likelihood at convergence	-782.91		

or customers. The coefficient is negative and significant with respect to the full-time alternative only. It appears that although the existence of regular face-to-face communication at work deters full-time home telecommuting, it does not automatically preclude its possibility, at least not in the employee's opinion.

Finally, the variable representing work end time (*e*) equals 1 where the commuter's typical work end time is at or later than 5:30 p.m. Again, the coefficient is negative and significant with respect to the full-time alternative only. Possibly this variable represents another measure of the importance of schedule flexibility, that is, someone must leave work before 5:30 p.m. to attend to personal matters. Therefore that person would be more inclined to select full-time telecommuting than an individual who has no such constraints on work end time.

There are five socioeconomic binary indicator variables in the model: gender, children, marriage, income, and age. There is also an interactive variable ("female with children") which equals 1 if the respondent is female and has children, otherwise it equals 0. The coefficient is positive with respect to both full-time and part-time telecommuting. In addition, gender variable, where the respondent is female, is also positive and significant with regard to the same alternatives. It is clear that women are more inclined to choose telecommuting than men.

The marital status variable is positive and significant with respect to all three nonnegative choices. There is also an income variable for men only (*i*) where the respondent reported the household income less than $25,000. The coefficient of the income variable is positive and related to the full-time alternative only. Because the income variable represents household income rather than individual income, this finding probably reflects reports in the literature that single men have a higher probability of working from home than married men (*12*). The age variable equals 1 when the respondent's age is over 50. The coefficient of age is negative and pertinent only to the part-time and "possibly" alternatives.

Variables that were examined in different forms, but omitted due to statistical insignificance, included commute mode, education, computer ownership, and various computer skill levels.

The model is calibrated with pooled data from the three cities included in the study. The transferability of the parameters is supported by the results of a likelihood ratio test comparing the log likelihood values of the pooled or fully restricted model shown in Table 3 and an unrestricted model in which each parameter is specific to each city (*15*). Tables

TABLE 4 Parameter Estimation Results for Austin

Independent Variable	Full-time	Part-time	Possibly
constant	-0.49 (-0.83)	0.35 (0.91)	0.69 (2.50)
round-trip commute time t; 0 if t≤20, t if 20 <t<80, 80 if t ≥80	0.012 (3.04)		
commute stops per week	0.062 (2.66)	0.062 (2.66)	
length of time with firm s; 1 if s ≥5 years, 0 otherwise	-0.67 (-2.55)	-0.67 (-2.55)	
avg. time using computer per day c; 1 if c >4 hours, 0 otherwise	0.79 (3.24)	0.79 (3.24)	
face-to-face communication f; 1 if response is several times per day with any group, 0 otherwise	-0.50 (-1.37)		
work end time e; 1 if e > 5:30 P.M., 0 otherwise	-0.61 (-2.01)		
females w/ children; 1 if yes, 0 otherwise	0.64 (1.48)	0.64 (1.48)	
males' household income y; 1 if y<$25,000 annually, 0 otherwise	1.59 (2.62)		
gender; 1 if female, 0 if male	0.52 (2.01)	0.52 (2.01)	
age a; 1 if a ≥50 years old, 0 otherwise		-1.21 (-2.30)	-1.21 (-2.30)
marital status; 1 if married, 0 otherwise	0.31 (0.87)	0.31 (0.87)	0.31 (0.87)
Number of Observations	346		
Log-likelihood at zero	-479.66	ρ^2=0.160	
Log-likelihood at convergence	-402.93		

TABLE 5 Parameter Estimation Results for Dallas

Independent Variable	Full-time	Part-time	Possibly
constant	-0.99 (-1.07)	0.081 (0.18)	-0.40 (-1.16)
round-trip commute time t; 0 if t≤20, t if 20 <t<80, 80 if t ≥80	0.014 (1.46)		
commute stops per week	0.032 (0.73)	0.032 (0.73)	
length of time with firm s; 1 if s ≥5 years, 0 otherwise	-0.46 (-1.17)	-0.46 (-1.17)	
avg. time using computer per day c; 1 if c >4 hours, 0 otherwise	0.76 (2.15)	0.76 (2.15)	
face-to-face communication f; 1 if response is several times per day with any group, 0 otherwise	-0.27 (-0.51)		
work end time e; 1 if e > 5:30 P.M., 0 otherwise	-0.89 (-2.27)		
females w/ children; 1 if yes, 0 otherwise	1.06 (1.78)	1.06 (1.78)	
males' household income y; 1 if y<$25,000 annually, 0 otherwise	-0.39 (-0.33)		
gender; 1 if female, 0 if male	-0.25 (-0.64)	-0.25 (-0.64)	
age a; 1 if a ≥50 years old, 0 otherwise		-0.42 (-0.80)	-0.42 (-0.80)
marital status; 1 if married, 0 otherwise	1.72 (3.44)	1.72 (3.44)	1.72 (3.44)
Number of Observations	173		
Log-likelihood at zero	-239.83	ρ^2=0.136	
Log-likelihood at convergence	-207.30		

4, 5, and 6 display the model estimation results for the cities separately. The test statistic for this likelihood ratio test is given by

$$2\{L_{\text{pooled}}(\beta) - [L_{\text{Austin}}(\beta) + L_{\text{Dallas}}(\beta) + L_{\text{Houston}}(\beta)]\}$$

This test statistic is χ^2 distributed with degrees of freedom equal to the number of restrictions, that is, $(K_{\text{Austin}} + K_{\text{Dallas}} + K_{\text{Houston}}) - K_{\text{pooled}}$, where K_j represents the number of coefficients on the corresponding model. Here the test statistic equals 2[782.91 − (402.93 + 207.30 + 158.83)] = 27.7. $\chi^2_{28,.05}$ = 41.3, so the hypothesis that the coefficients are identical across cities cannot be rejected.

CONCLUSIONS

As Figure 1 implies, the decision-making process involved in the telecommuting choice is rather complex. It is likely that in most cases today the process never commences from lack of awareness on the part of individuals involved: executives, managers, and employees alike. In time, as the concept spreads via various media, perhaps more workers will be able to choose their workplace much as they would choose a commute mode. The availability of the telecommuting option is the crucial constraint to the employee decision described in the left-hand portion of Figure 2 and modeled in Table 3. Still, the results of this exploratory analysis indicate that stated preference information can be useful in modeling the employee telecommuting decision. The model is a step toward a profile of the likely future telecommuter.

Throughout the literature that attempts to evaluate telecommuting's potential impact on society, the universal complaint is that no data exist to justify estimates of the information labor force. Who are they? How many are there? Estimates vary widely. The most commonly referenced figure is from Porat (1977), who estimated that about half the labor force at that time was information workers (*16*). When the supply of telecommutable jobs within the workforce is better understood, the task of forecasting the amount of telecommuting and its impact on a region's transportation system as a demand management strategy will be facilitated.

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TABLE 6 Parameter Estimation Results for Houston

Independent Variable	Full-time	Part-time	Possibly
constant	0.071 (0.08)	-0.24 (-0.42)	0.24 (0.58)
round-trip commute time t; 0 if t≤20, t if 20 <t<80, 80 if t ≥80	0.0069 (0.81)		
commute stops per week	0.11 (1.88)	0.11 (1.88)	
length of time with firm s; 1 if s ≥5 years, 0 otherwise	-0.67 (-1.62)	-0.67 (-1.62)	
avg. time using computer per day c; 1 if c >4 hours, 0 otherwise	1.27 (3.03)	1.27 (3.03)	
face-to-face communication f; 1 if response is several times per day with any group, 0 otherwise	-1.00(-1.82)		
work end time e; 1 if e > 5:30 P.M., 0 otherwise	-1.00 (-2.33)		
females w/ children; 1 if yes, 0 otherwise	1.28 (1.54)	1.28 (1.54)	
males' household income y; 1 if y<$25,000 annually, 0 otherwise	8.50 (0.16)		
gender; 1 if female, 0 if male	0.60 (1.37)	0.60 (1.37)	
age a; 1 if a ≥50 years old, 0 otherwise		0.13 (0.21)	0.13 (0.21)
marital status; 1 if married, 0 otherwise	0.86 (1.48)	0.86 (1.48)	0.86 (1.48)
Number of Observations	143		
Log-likelihood at zero	-198.24	ρ^2=0.199	
Log-likelihood at convergence	-158.83		

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