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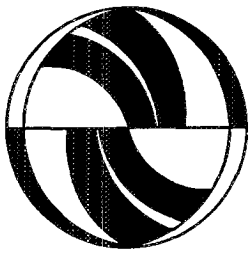

Modeling the Choice of Telecommuting Frequency in California: An Exploratory Analysis

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The University of California
Transportation Center

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NORTH-HOLLAND

Modeling the Choice of Telecommuting Frequency in California: An Exploratory Analysis

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ABSTRACT

This study explores the individual's choice of telecommuting frequency as a function of demographic, travel, work, and attitudinal factors. To do this, multinomial logit models are estimated using data collected in a recent survey of employees from three public agencies in California. Separate models are estimated, one for data collected from the Franchise Tax Board in Sacramento, one for data from the Public Utilities Commission in San Francisco, and one for data collected from employees of the City of San Diego. The results show that the most important variables in explaining the choice of frequency of telecommuting from home were the presence of small children in the household (irrespective of respondent gender), the number of people in the household, gender of respondent, number of vehicles in the household, whether respondent recently changed departure time for personal reasons, degree of control over scheduling of different job tasks, supervisory status of respondent, the ability to borrow a computer from work if necessary, and a family orientation. The empirical analysis also shows that model results are not transferable among the three organizations studied.

Introduction

Telecommuting—working at home or at a location close to home instead of commuting to a conventional work location at the conventional time—is currently enjoying a surge in popularity. A survey conducted in the spring of 1993 found that 4%-5% of the adult U.S. workforce now telecommutes at least part time [3]. This represents a growth rate of 20% per year for the previous 3 years. Legislation or executive branch policy at the federal level, in several states, and in numerous metropolitan areas has been enacted in recent years that encourages telecommuting, either directly or indirectly [9]. The results of early telecommuting projects are in and they are encouraging. Travel and emission reductions have been documented and telecommuting has been shown to be a desirable work option for (some) workers as it provides more choice and flexibility in the scheduling

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of work and nonwork activities [12]. Benefits to employers are reported to include improved productivity, morale, quality of work, management technique and employee retention, as well as reduced use of sick leave [4].

The promise of telecommuting as a public policy measure stems largely from its conventionally viewed status as a substitute for travel, specifically for the commute trip. Commute trips typically account for 30%–40% of urban vehicle-miles traveled [14]. Therefore, any technology that can substantially reduce that volume of travel, and its contribution to urban freeway congestion, will also benefit air quality and energy consumption.

One central question about telecommuting is the rate at which it will be adopted. Clearly more and more people are telecommuting, but forecasting remains problematic. Yet is is important to be able both to assess the impact telecommuting is likely to have on travel, fuel consumption, air quality, urban form, and other policy issues of interest, and to predict the impact of various policy measures on the demand for telecommuting. Accurately forecasting levels of telecommuting is integral to both of these tasks.

Several data-collection efforts have been undertaken recently to empirically evaluate the behavioral process underlying the adoption of telecommuting. Causal models of the individual's choice to telecommute will provide a useful foundation for meaningful aggregate forecasts of telecommuting penetration. Such models of the individual choice have been developed by several investigators [2, 11, 16].

Bernardino, Ben-Akiva, and Salomon [2] postulate a two-tiered decision tree for the adoption of telecommuting by an individual. First, the decision is made whether or not to telecommute. This is characterized as a long-term, fairly stable decision. Once the decision has been made to telecommute, the individual chooses the frequency of this work option. Although the authors recognize that in some cases the frequency to telecommute may be an integral part of the first decision, they assume that most often the individual will have the near-term flexibility to vary the frequency. A pilot study using stated preference data (i.e., using what people say they will do as opposed to observing what they actually do) from 100 survey respondents examined the hypothetical choice to adopt or not adopt telecommuting. An ordered probit model estimated from the data indicated that having to pay telecommuting costs (phone bills, equipment provision, etc.) made people less inclined to adopt telecommuting. As the number of children in the household increased, so did the likelihood of adopting telecommuting. Telecommuting was found to be more attractive to those who did not have the option than to those who currently did.

Also using stated preference data, Sullivan et al. [16] explored the choice to telecommute through estimation of a four-choice multinomial logit model. The four hypothetical choices were (1) yes, telecommute full-time, (2) yes, telecommute part-time, (3) possibly, and (4) no. Pooled data from 694 survey respondents from three Texas cities was used to estimate the model. Most coefficients for statistically significant variables were found to be positive for at least one alternative. These variables included round-trip commute time, average number of stops per week on the commute trip, degree of work-related computer use, marital status, income (if male), whether the respondent was female, and whether the respondent was female with children. Coefficients for length of employment, requirement for face to face communication, time when the work day ends, and age were statistically significant and negative for at least one choice alternative.

Without doubt, previous empirical and conceptual studies on telecommuting have provided valuable information on individuals' propensity to telecommute and the likely impacts of telecommuting decisions. The complexity of the telecommuting decision has made it difficult to study, however. In terms of an individual's propensity to telecommute, data limitations have often constrained the behavioral analysis and prevented important questions from being answered. Mokhtarian and Salomon [11] propose a conceptual model based on the interplay of key decision factors. These factors are constraints that prevent telecommuting from being adopted, facilitators that allow telecommuting to be adopted, and drives that motivate an individual to adopt telecommuting. The absence of constraints alone is insufficient to ensure adoption of telecommuting by an individual. Telecommuting must also assist in the satisfaction of one or more drives. These drives define a person's life-style and include the magnitude and form of participation in work, family, leisure, travel, and ideological activities. Although a well-defined conceptual model has been developed, empirical estimations of that model based on a recently administered survey have not yet been completed. The present paper offers some exploratory models of telecommuting adoption based on that highly detailed survey. The objective of these models is to shed some new light on individuals' telecommuting decisions. Specifically, we will study individuals' observed telecommuting frequency (i.e., revealed preference as opposed to stated preference) as a function of demographic, attitudinal, work, and travel characteristics, and explore issues of behavioral transferability among individuals from different employers and different telecommuting programs. The results of this study will provide a better understanding of telecommuting behavior and the rate of adoption of the telecommuting work option.

The paper begins with a description of the survey instrument and a statistical summary of collected data. Next, a behavioral model structure is selected, empirical results are discussed, and model specification tests are conducted. The paper concludes with a summary and discussion of the implications of our findings.

Survey Method and Data Description

The survey was 14 pages long (excluding the cover letter and a blank page for comments) and was divided into six sections. The first section requested information on previous awareness of, and experience with, telecommuting and working from home. The second collected data on job characteristics, including occupation, duration of employment, amount of time spent on certain work activities, degree of schedule control, and the ability to establish a home office. Information on ability to telecommute and attitudes toward the advantages and disadvantages of telecommuting was requested in the third section of the survey. The fourth section collected information on life-style decisions related to telecommuting that the respondent had made or was considering. The fifth section asked for views on a variety of issues that directly or indirectly relate to telecommuting, and the final section requested general socioeconomic and travel behavior information. A copy of the survey is provided in Mannering [6].

Following an internal pretest, the survey was field-tested in November and December 1992 at two agencies of the State of California: the Franchise Tax Board (FTB) in Sacramento, and the Public Utilities Commission (PUC) in San Francisco [10]. A larger survey distribution was made in December 1992 to a sample of employees of the City of San Diego.

In order to improve response rate and the chances of capturing information on actual telecommuting behavior, the sample included all known telecommuters at the FTB and PUC. Also, for nontelecommuting employees, job categories known to be unsuitable for telecommuting were not surveyed, although the sample included both professional and clerical occupations. After excluding unsuitable occupations, every n^{th} employee was

selected from an alphabetized list. A total of 160 surveys were distributed to employees in each agency. No incentives for completion were offered for the field tests [10].

In San Diego, the survey was sent to all employees in six, selected city departments: Attorney, Auditor, Building Inspection (which had the second highest number of existing telecommuters of any City department), Engineering and Development, Financial Management, and Planning and Purchasing. These organizations were chosen based on apparent suitability of function for telecommuting, willingness of the departmental director to participate in the study, number of existing telecommuters in the department, and the combined sizes of the selected departments. Within departments, a sample of a diverse cross section of employees was desired in order to capture as broad a spectrum of information as possible. A total of 1428 surveys were distributed and an incentive for completion of the survey was offered to City of San Diego respondents. A drawing for $100 was held from the pool of city employees completing and returning the survey.

The response rates from the Franchise Tax Board and Public Utilities Commission were identical. Of the 160 surveys sent to employees at each agency, 56.3% or 90 surveys were completed and returned. Given the lack of monetary incentive and the length of the survey, this suggests a high level of interest in the subject. For the City of San Diego, 44.0% or 629 out of 1428 surveys were returned. This rate of response is also quite acceptable.

Both the sampling bias (the population sampled is not necessarily representative of the workforce as a whole) and the self-selection response bias (those who returned the survey were likely to differ materially from those who did not) mean that the three samples can not be considered representative. In exploratory research of this type, however, it is expected that a great deal can be learned about the general importance of the various explanatory factors of telecommuting choice, even if the proportions of those choosing telecommuting in our samples do not replicate population shares.

The following three sections describe general characteristics of our three samples. Note that the sample percentages given below exclude missing data (i.e., if the respondent's choice of telecommuting frequency was not available, the respondent was excluded from the summary statistics discussed). Thus, the sample percentages given below are only for those respondents included in the subsequent empirical analysis of telecommuting frequency.

SAN DIEGO DATA

The San Diego sample comprised 53.1% females, most falling into the 31–40 year (38.6%) and 41–50 year (28.3%) age brackets. The sample was well-educated with 25.0% completing a graduate degree and an additional 28.6% graduating from a 4-year college. More respondents (31.6%) had a yearly household income of $35,000 to $54,999 than any other category, with the next most populous group (23.2%) having an income of $55,000 to $74,999. The average number of people in the household was 2.66, with the mean number of full-time workers being 1.57 and the mean number of part-time workers 0.23. In addition, 10.8% of households had children under 2 present and 15.0% contained children between 2 and 5 years old.

The average number of vehicles in the household was 1.91. Most people disagreed with the statement that their car is a status symbol, considering it only a convenience. The average one-way commute distance was 12.86 miles for City of San Diego respondents, whereas the commute to work took 26.03 minutes on average and the commute home took 28.53 minutes. Within the past year, 51.2% reported changing work trip departure time to avoid congestion, 39.5% changed departure time for personal reasons, and 31.5% changed their mode of travel to work (e.g., from bus to carpool).

The average length of employment within the respondent's current department was 5.99 years, with 8.71 years the average time with present employer, and 8.53 years the average length of time in present occupation. In regard to occupations reported, 11.6% of respondents were managers, 58.7% were professional or technical employees, and 25.0% held clerical or administrative support positions.

Regarding personal attitudes and awareness, 74.0% knew someone who telecommuted. Respondents preferred to spend an unexpected extra hour on themselves (48.9%) or with their family (37.6%) in preference to spending it on a "cause" they believe in (9.9%) or work (3.6%).

Turning to the dependent variable to be used in the forthcoming analysis, only 16.4% of respondents reported that they were currently telecommuting from home. However, 81.3% believed that at least some part of their job could be done from home, and of those, 75.4% had already set aside at least part of a room for a home office.

FRANCHISE TAX BOARD DATA

A higher percentage of Franchise Tax Board than San Diego respondents were female (70.0%). Most FTB respondents were in the age 41–50 (39.3%) and 31–40 (36.0%) brackets. The sample was well-educated with 22.2% completing a graduate degree and an additional 18.9% graduating from a 4-year college. More respondents (26.7%) had a yearly household income of $55,000 to $74,999 than any other category, with the next most populous group (26.4%) having an income of $35,000 to $54,999. The average number of people in the household was 2.72, with the mean number of full-time workers being 1.61 and the mean number of part-time workers 0.33. In addition, 4.5% of households had children under 2 present and 12.5% had children between 2 and 5 years old.

The average number of vehicles in the household was 2.18. Most people disagreed with the statement that their car is a status symbol, viewing it as only a convenience. The average one-way commute distance was 16.13 miles for FTB respondents, whereas the commute to work took 26.57 minutes on average and the commute home took 30.37 minutes. Within the past year, 61.1% reported changing work trip departure time to avoid congestion, 52.8% changed departure time for personal reasons, and 28.4% changed their mode of travel to work.

The average length of employment within the respondent's current department was 9.64 years, with 11.20 years the average time with present employer, and 7.84 years the average length of time in present occupation. In regard to occupations reported, 15.6% of respondents were managers, 68.9% were professional or technical employees, and 11.1% held clerical or administrative support positions.

Regarding personal attitudes and awareness, 83.3% knew someone who telecommuted. Respondents preferred to spend an unexpected extra hour on themselves (45.5%) or with their family (42.0%) in preference to spending it on a "cause" they believe in (10.2%) or work (2.3%).

Turning to the dependent variable to be used in the forthcoming analysis, 45.5% of respondents reported that they were currently telecommuting from home. Also, 89.5% believed that at least some part of their job could be done from home, and of those, 88.2% had already set aside at least part of a room for a home office.

PUBLIC UTILITIES COMMISSION DATA

Only 34.8% of Public Utilities Commission respondents were female, with most falling into the 41–50 year (43.8%) and 31–40 year (21.3%) age brackets. The sample was very well-educated with 47.2% completing a graduate degree and an additional 27.0% graduating from a 4-year college. More respondents (36.0%) had a yearly household

income of $55,000 to $74,999 than any other category, with the next most populous group (23.6%) having an income of $75,000 to $94,999. The average number of people in the household was 2.81, with the mean number of full-time workers being 1.41 and the mean number of part-time workers 0.30. In addition, 6.7% of households had children under 2 present and 16.9% had children between 2 and 5 years old.

The average number of vehicles in the household was 2.81. Most people disagreed with the statement that their car is a status symbol, considering it only a convenience. The average one-way commute distance was 22.39 miles for PUC respondents, whereas the commute to work took 51.53 minutes on average and the commute home took 54.71 minutes. Within the past year, 34.9% reported changing work trip departure time to avoid congestion, 35.6% changed departure time for personal reasons, and 34.9% changed their mode of travel to work.

The average length of employment within the respondent's current department was 8.15 years, with 13.69 years the average time with present employer, and 12.47 years the average length of time in present occupation. In regard to occupations reported, 27.8% of respondents were managers, 65.6% were professional or technical employees, and 4.4% held clerical or administrative support positions.

Regarding personal attitudes and awareness, 100.0% knew someone who telecommuted. Respondents preferred to spend an unexpected extra hour on themselves (44.9%) or with their family (41.6%) in preference to spending it on a "cause" they believe in (10.1%) or work (3.4%).

Turning to the dependent variable to be used in the forthcoming analysis, 41.6% of respondents reported that they were currently telecommuting from home. Also, 87.8% believed that at least some part of their job could be done from home, and of those, 85.9% have already set aside at least part of a room for a home office.

COMPARISON OF DATA SOURCES

Initial comparison of the descriptive statistics revealed a number of interesting differences among the three data sources. In particular, substantially more FTB respondents were female than those responding from San Diego or PUC: 70.0%, 53.1%, and 34.8%, respectively. FTB and PUC employees were older, with higher household incomes, than San Diego employees. FTB and PUC respondents reported fewer household members than respondents from San Diego. PUC respondents were better educated than the others, whereas San Diego reported fewest full-time workers and FTB reported the lowest percentage of households with children under 5 years old.

Moving to travel behavior, the average number of vehicles varied from 1.91 to 2.81 per household. The average commute time and distance were substantially higher for San Francisco-based (PUC) employees, than for respondents in San Diego or Sacramento (FTB), and substantial percentages from all sources reported recently changing work trip departure time to avoid congestion or for personal reasons. Substantial percentages from San Diego, FTB, and PUC also reported switching commute modes.

Employees at PUC and FTB reported being employed for a longer period of time in their current department than did those in San Diego. PUC also had a noticeably greater percentage of managers and a lower percentage of clerical workers among respondents than either San Diego or FTB.

FTB and PUC both reported much higher percentages of current telecommuters than San Diego (45.% and 41.6%, versus 16.4%) although high percentages of respondents from all three sources reported believing that at least some of their job could be done at home. This is not particularly surprising given the sampling design. Most people

TABLE 1
Difference in Means for Key Socioeconomic and Other Variables

Variable	San Diego versus FTB	San Diego versus PUC	FTB versus PUC
Sex	Yes	Yes	Yes
Age	Yes	Yes	Yes
Educational background	Yes	Yes	Yes
Household income before taxes	No	No	No
Number of people in household	No	Yes	No
Number of full-time workers in household	No	No	No
Number of part-time workers in household	Yes	No	No
Number of vehicles in household	Yes	Yes	No
Time in current department	Yes	Yes	No
Time with current employer	No	Yes	Yes
Time in current occupation	Yes	Yes	Yes
One-way distance to work (miles)	No	Yes	Yes
Time to go from home to work (minutes)	No	Yes	Yes
Time to go from work to home (minutes)	Yes	Yes	Yes
Do you currently telecommute from home?			

Yes = different at or below the 0.05 significance level.

at San Diego, FTB, and PUC reported knowing someone who telecommutes: 74.0%, 83.3%, and 100.0%, respectively.

Although interesting, not all differences between data sources were significant. Table 1 summarizes the statistical significance of observed differences in means of key variables between San Diego and FTB data, San Diego and PUC data, and FTB and PUC data. All variables, except number of people in the household and number of part-time workers in the household, included in this table have statistically different means at or below the 0.05 significance level (95% confidence) in at least one of the three comparisons.

Model Structure

A variety of statistical techniques are available to develop a model to predict the likelihood of an individual choosing a particular telecommute frequency. Models based on both ordered and unordered responses were considered for use in the analysis of the survey data. For the reasons described below, a model that assumed responses to be unordered was deemed most suitable.

One approach to analyzing the survey data is to consider the individual's choice of telecommuting frequency as an ordered response. Ordered-response questions (e.g., rating items on a scale of 0 to 10) are used frequently in marketing surveys and can be modeled using ordered logit or probit models [5]. At first sight, this would appear to be a promising methodology as the dependent variable for the analysis asks how much the respondent currently telecommutes from home and allows seven possible responses: not at all, less than once a month, about 1–3 days a month, 1–2 days a week, 3–4 days a week, 5 days a week, and occasional partial days. Discarding the final category as incongruent with the others, the remaining six choices appear nicely ordered from low to high frequencies.

The use of an ordered response model in this case has significant limitations, however. The most critical disadvantage is that an ordered model assumes monotonically increasing (or decreasing) desirability of the choice alternatives for each explanatory variable. For example, as the value of an explanatory variable like income increases, telecommuting

5 days/week would be more desirable than telecommuting 3–4 days/week, which in turn would be more desirable than telecommuting 1–2 days/week, and so on. This modeling approach cannot accommodate explanatory variables that would favor a mid-range choice alternative over higher and lower telecommute frequency choices.

Initial model exploration, which was confirmed in the final estimation results presented later in this section, indicated that there is a substantial proportion of explanatory variables that have coefficients significant for moderate frequency choices but not for low or high frequency alternatives. It is shown elsewhere [6] that the ordered model had substantially worse overall fit as measured by the log-likelihood at convergence. This suggests that use of an ordered response model would be inappropriate in our context.

Two modeling approaches that use unordered responses were considered. These were a multinomial (simple) logit structure and a nested logit structure. The nested structure was rejected based on model specification tests (which will be discussed later). The use of a multinomial logit structure required that the telecommute frequency estimates be grouped into discrete, independent categories. Statistical analysis of the data suggested two underlying choice structures were possible. The first implied a four-choice model: never telecommute, low-frequency telecommute (less than once/month), moderate-frequency telecommute (1–3 days/month) and high-frequency telecommute (at least 1 day/week). Initial estimation results suggested that most people in the sample made little distinction between low- and moderate-frequency telecommuting so the choice categories were modified into the following three choices: never telecommute, infrequently telecommute (less than once/week) and frequently telecommute (at least once/week). This second choice structure was found to yield interpretable estimation results for the three models presented later in this section.

To formally define the model structure used, let U define a linear function of variables that explain an individual's probability of choosing never, infrequent, or frequent telecommuting such that,

$$U_{ni} = \beta_{0i} + \beta_{1i}H_n + \beta_{2i}T_n + \beta_{3i}W_n + \beta_{4i}P_n + \varepsilon_{ni} \quad (1)$$

where U_{ni} is the value of the function determining the probability of choosing frequency i (i.e., never, infrequent, frequent) for individual n, H_n is a vector of household and socioeconomic characteristics (e.g., income per capita, number of people in the household) for individual n, T_n is a vector of household transportation characteristics and individual travel behavior (e.g., vehicles per capita, perception of automobiles as status symbols, recent work trip departure time change), W_n is a vector of attributes of an individual's work or attitudes toward work (e.g., hours worked in a 2-week period, length of time in present occupation), P_n are personal attitudes and awareness (e.g., family and friends are more important than work, satisfaction with life, familiarity with telecommuting), β,s are vectors of statistically estimable parameters, and ε_{ni} is an error term added to account for unobserved factors influencing the choice of telecommute frequency. The β,s are allowed to vary across choice alternatives. Unlike most transportation mode choice models, the attribute vectors H_n, T_n, W_n, and P_n do not vary across choice alternatives because the data used for estimation does not include alternative specific information. In the absence of such alternative specific data it is convenient to select one of the alternatives as a base and normalize the β coefficients to be zero for that alternative. This is because coefficients can only be estimated for, at most, two of the three alternatives. Attempting to estimate variable coefficients for all three alternatives is not possible due to the perfect collinearity that will exist. In the models presented below, we take the "never telecommute" alternative to be the base. This creates the possibility that, for some variables, the coefficients for "infrequently" and "frequently" alternatives will be identical. This is just an artifact of our formulation (i.e., constraining the "never" alternative to be zero) and, in such cases, is equivalent to having that variable's coefficient (with same magnitude but opposite sign) in the "never" alternative only.

The function U_{ni} can also be considered as

$$U_{ni} = V_{ni} + \varepsilon_{ni} \quad (2)$$

where V_{ni} is a linear function of observed factors and ε_{ni} represents random unobserved factors that determine the choice of telecommuting frequency. It can easily be shown that if ε_{ni}s are assumed to be generalized extreme value distributed, then the probability of an individual choosing never, infrequent, or frequent telecommuting frequencies is given by the standard multinomial logit model,

$$P_{ni'} = \frac{e^{V_{ni'}}}{\sum_i e^{V_{ni}}} \quad (3)$$

where $P_{ni'}$ is the probability of individual n choosing telecommuting frequency alternative i' (never, infrequent, frequent) and all other terms as previously defined. Equation (3) is estimable by standard maximum likelihood techniques as discussed by McFadden [7] and other sources. This model structure allows the exploration of factors underlying the selection of telecommuting frequency.

Three separate models were estimated. One model used San Diego data, one FTB data, and one PUC data. Model specification tests described later in this paper confirmed that separate models were appropriate because data from the three sources should not be pooled.

Estimation Results

As mentioned previously, the frequency of telecommuting was structured into three choices: never, infrequently (less than once per week), and frequently (at least once per week). For all final models, significant variables capturing attributes of respondents' work and attitudes toward work outnumbered significant variables representing household attributes, transportation and travel behavior, and personal attitudes and awareness. All coefficients in the final models presented below had a t-statistic for a two-tailed distribution with a significance level at or below 0.10 (at or above the 90% confidence level).

SAN DIEGO MODEL

The results of the San Diego model estimation are shown in Table 2. Variables from all four categories—household, transportation, work, and personal attitude and awareness—were found to be significant in explaining the choice of frequency of telecommuting among City of San Diego employees. Work-related attributes were especially abundant in this model, accounting for ten variables. This compares with three each for household and transportation characteristics, and four personal attitude and awareness variables.

Household Attributes

The coefficient for number of people in the household was found to be positive for the choice to telecommute frequently. This may represent a desire for increased work/commute flexibility in the face of increasingly complex family interactions. On the other hand, the coefficient of the indicator for the special condition of women with children under 5 years old present in the household was positive and significant only for the choice

TABLE 2
Multinomial Logit Estimation Results of the Choice of Telecommuting Frequency for City of San Diego Employees

Independent variable	Coefficient estimate (*t*-statistic) associated with each telecommuting frequency dependent variable[a]	
	Infrequently	Frequently
Constant	−5.76	−7.49
	(−6.29)	(−2.79)
Number of people in household	—	0.35
		(2.25)
Female with small children indicator (1 if female and children under 5 present in household, 0 otherwise)	1.01	—
	(2.19)	
Home-office indicator (1 if have home office space, 0 otherwise)	—	2.48
		(2.33)
Vehicles per capita in household	0.87	0.87
	(2.06)	(2.06)
Automobile is status symbol (5-point scale: 1 = strongly disagree to 5 = strongly agree)	—	−0.64
		(−2.26)
Departure time change indicator (1 if work trip departure time has changed for personal reasons in the past year, 0 otherwise)	0.67	—
	(2.03)	
Hours worked in a 2-wk period, including paid and unpaid overtime	—	−0.0325
		(−1.76)
Unpaid overtime indicator (1 if worked unpaid overtime in the past 6 months, 0 otherwise)	−1.17	—
	(−3.17)	
Work at home indicator (1 if took work home in the past 6 months, 0 otherwise)	2.19	—
	(4.41)	
Supervision indicator (1 if supervises other supervisors, 0 otherwise)	1.15	1.15
	(2.88)	(2.88)
Clerical occupation indicator (1 if occupation is clerical or administrative support, 0 otherwise)	−0.83	−0.83
	(−1.72)	(−1.72)
Full-time work indicator (1 if worked full-time instead of part-time in the past 2 years, 0 otherwise)	—	1.29
		(2.49)
Remote work indicator (1 if more than 24 hours/week is work done remotely, 0 otherwise)	1.46	—
	(2.92)	
Schedule control indicator C (1 if high control over work done remotely, 0 otherwise)	0.70	0.70
	(2.37)	(2.37)
Schedule control indicator D (1 if high control over location specific work, 0 otherwise)	—	0.89
		(1.88)
Productivity difficult in work place (5-point scale: 1 strongly disagree to 5 = strongly agree)	0.24	0.24
	(2.08)	(2.08)
Telecommuting familiarity indicator (1 if knows a telecommuter, 0 otherwise)	1.23	1.23
	(2.71)	(2.71)
Lack of self-discipline (5-point scale: 1 = strongly disagree to 5 = strongly agree)	−0.25	−0.25
	(−1.70)	(−1.70)
Family orientation indicator (1 if an extra hour would be spent with family, 0 otherwise)	—	−1.08
		(−2.03)
Satisfied with life (5-point scale: 1 = strongly disagree to 5 = strongly agree)	—	0.70
		(2.05)
Model statistics		
Log-likelihood at zero		−475.70
Log-likelihood of market-share		−266.49
Log-likelihood at convergence		−198.05
ρ^2		0.58
ρ^2 (adjusted)		0.56
Total number of observations	433	100.00%
Number who chose:		
Never telecommute	349	80.60%
Infrequently telecommute	56	12.93%
Frequently telecommute	28	6.47%

[a] Coefficients for the choice never to telecommute were normalized to zero for this estimation.

to telecommute infrequently. This could indicate a desire in this socio-economic group to telecommute as a flexible, occasional means of attending to child-related illnesses and other emergencies.

The home-office indicator coefficient was positive for frequent telecommuting, which is sensible because home-based telecommuting on a regular basis is obviously made easier when all or part of a room has been set aside for home office functions. It should be noted that a home office can meet many needs other than that of a base for telecommuting, however, thus allaying concerns that this indicator may be endogenous. This attribute is also very likely capturing an income effect represented by the ability to afford a larger house. Telecommuting is expected to be more available to individuals with high-income, high-autonomy jobs.

Transportation and Travel Behavior Attributes

The coefficient for vehicles per capita was positive for both infrequent and frequent telecommuting. This is reasonable as adoption of telecommuting may result in disruption of established, multiple-occupancy vehicle (carpools, vanpools, subscription buses, etc.) commute patterns, resulting in a greater requirement for single-occupancy commute trips on noncommuting days. This may also be capturing an income effect, where increasing vehicles per capita represents increasing affluence, and a residence location effect. It is expected that individuals living farther from work, especially in suburban or exurban areas, will be especially interested in telecommuting as a work/commute option. The urban structure and lack of useful mass transit in such areas often dictates that most or all licensed drivers in a household have a vehicle for access to services and employment.

Not surprisingly, viewing an automobile as a status symbol had a negative effect on the propensity to choose frequent telecommuting. On the other hand, changing work trip departure time for personal reasons in the past year had a positive effect on the choice of infrequent telecommuting. This may reflect an underlying, continuing dissatisfaction with the commute and some mismatch between the time commitment required for work versus nonwork activity. This attribute reinforces the effect expressed by the female-with-small-children indicator discussed above. Because the coefficient for change of departure time was significant for infrequent telecommuting, it is interesting that the coefficient was not also significant for frequent telecommuting. This suggests that the departure time change resolved all but occasional scheduling difficulties. Alternately, it may indicate that the San Diego telecommuting program is not so mature that frequent telecommuting is easily chosen.

Work Attributes and Attitudes Toward Work

As the hours worked in a 2-week time period (including paid and unpaid overtime) increase, a mild tendency away from frequent telecommuting was expressed. The negative sign of this coefficient may represent a tendency for increased hours to accompany increased responsibility for supervision of nonsupervisory personnel. For infrequent telecommuting only, the coefficient for the unpaid overtime indicator was also negative, whereas the coefficient for taking work home was positive. The implication of these two indicator variables is that the frequency of telecommuting depends on both the amount and type of work performed by an individual. Some work, in certain quantities, is more suited for performance at the office than at home.

One interesting but quite plausible finding was that if an individual supervised other *supervisors* (as opposed to nonsupervisory staff), the coefficient for frequent and infrequent telecommuting was positive. This may be expressing one or more underlying factors, such as trust of those employees the individual is supervising (i.e., other supervisors who

presumably would not be in supervisory positions if they were not reliable individuals), a high degree of work-related autonomy, and a self-contained job function. The element of trust is consistent with the observation that, for nonsupervisory employees, the ability to telecommute depends as much on management belief that the employee will be productive when not visually supervised as it does on suitability of job function.

As expected, the clerical-occupation-indicator coefficient was negative for both infrequent and frequent telecommuting. This might be explained by a general lack of job control, lack of functional suitability, and may also, as discussed above, denote a general unwillingness on the part of management to believe that this type of employee will be productive when away from the office. If an individual changed from working part-time to working full-time in the past 2 years, he or she was more likely to telecommute frequently. This may reflect greater trust of full-time employees, more frequent and thus onerous commutes, an income effect, or a constraint on who is allowed to telecommute (i.e., the option is offered only to full-time employees of the City). It may also represent a maternity or disability leave effect. Telecommuting could offer a way to transition from part-time to full-time work without increasing the number of commute days.

The coefficient for the remote-work indicator was positive for infrequent telecommuting. In other words, if more than 24 hours/week of the work an individual does with others is done remotely (e.g., making and receiving telephone calls), the choice to telecommute infrequently was more likely. This may indicate the interest in telecommuting for this type of job, but also reflect a barrier in that advance planning and advanced telephone line switching between home and the office may be required for frequent home-based telecommuting (i.e., an individual may prefer to telecommute more frequently, but only be able to choose infrequent telecommuting due to preexisting constraints).

The signs of coefficients for work control indicators were as expected. Coefficients for frequent and infrequent telecommuting were positive when a high degree of control over work done remotely was present, and the coefficient for frequent telecommuting was positive for individuals with high control over work performed at specific locations (i.e., site visits, sales calls, service/maintenance calls, court, etc.). This last is interesting because it highlights that much of the "paperwork" associated with this type of work can be handled as easily from home as from the office. The advent of portable computers, facsimile machines, and modems has undoubtedly done much to foster this paperwork decentralization.

Not surprisingly, the more an individual felt that an acceptable level of productivity at the conventional workplace was difficult to obtain, the more frequent or infrequent telecommuting was chosen.

Personal Attitudes and Awareness

As expected, those who knew someone who telecommuted were more likely to telecommute themselves, frequently or infrequently. This can represent both the availability of telecommuting to the individual's work unit, and/or familiarity with the concept. Also as expected, the more a respondent agreed he or she lacked self-discipline, the less telecommuting was chosen as a work/commute option.

Two interesting variables, representing personal attitudes, were the family-orientation indicator and how satisfied with life was the respondent. For the first, the coefficient was negative for frequent telecommuting. This suggests that for people who would spend an extra hour that became available with their family, frequent home-based telecommuting may be an unwelcome intrusion into the sphere deliberately set apart for family time and activities. For the second, the positive coefficient indicates that frequent

telecommuting appeals to those who are generally satisfied with their life. It is intriguing to speculate that this is an indirect expression of the degree of control an individual has over life, especially employment conditions. If a high degree of control, particularly over one's job, leads to general life satisfaction, and if that same control allows the individual to make the choice to telecommute, then general life satisfaction should be correlated with the choice to telecommute. Conversely, this implies that a lack of general life satisfaction is related to lack of job control, and thus to an inability to choose to telecommute (i.e., the individual is *falsely perceived* as freely choosing to never telecommute).

Constants

The negative sign of the constant coefficients indicates that, for both the choice to telecommute infrequently and the choice to telecommute frequently, the mean of unobserved effects is negative. In other words, effects exist that were not captured by the model that favor the choice never to telecommute. This is not surprising for several reasons including: survey respondents may not be able to telecommute because no program explicitly exists; and the structure of work in modern organizations is a result of a myriad of interconnecting policies, laws, operating procedures, and social customs that often do not permit telecommuting, even though the nature of the work itself and the desire of the worker would suggest otherwise.

Model Statistics

The model was estimated using 433 observations out of the 629 total available data records, the remainder having missing data on one or more of the model variables. The null hypothesis that all coefficients are zero (i.e., all telecommuting frequencies are equally likely to be chosen) can be tested through a likelihood ratio test. The statistic for this test is given by

$$-2[\mathcal{L}(0) - \mathcal{L}(\beta)]$$

where

$\mathcal{L}(0)$ = initial log-likelihood
$\mathcal{L}(\beta)$ = log-likelihood at convergence

The test statistic χ^2 distributed with K degrees of freedom, where K is the number of coefficients estimated. For the San Diego model, the χ^2 value was 555.30 with 22 degrees of freedom. This means that the null hypothesis that all coefficients are zero can be rejected with greater than 99.9% confidence.

The null hypothesis that all coefficients, except those of the alternative-specific constants, are zero (i.e., the explanatory variables contribute nothing since the choice probabilities are entirely defined by the market-share of the choice alternatives) can also be tested through a likelihood ratio test. The test shows that this null hypothesis can be rejected with greater than 99.9% confidence ($\chi^2 = 136.8$, df = 20).

The ρ^2 value for the model was 0.58, and ρ^2-adjusted (adjusted for the number of coefficients) was 0.56. These values are quite satisfactory for exploratory research into such a complex behavioral process.

FRANCHISE TAX BOARD MODEL

The results of the Franchise Tax Board Model are found in Table 3. As in the San Diego model, variables from all four categories—household, transportation, work, and personal attitudes and awareness—were found to be significant in explaining the choice of frequency of telecommuting among FTB employees. Work-related attributes were

TABLE 3
Multinomial Logit Estimation Results of the Choice of Telecommuting Frequency for Franchise Tax Board Employees

Independent variables	Coefficient estimate (*t*-statistic) associated with each telecommuting frequency dependent variable[a]	
	Infrequently	Frequently
Constant	−10.89	−14.13
	(−2.93)	(−3.44)
Income per capita in household	0.00016	0.00016
	(3.43)	(3.43)
Small children indicator (1 if children under 5 are present in household, 0 otherwise)	3.19	3.19
	(2.27)	(2.27)
Departure time change indicator (1 if work trip departure time has changed for personal reasons in the past year, 0 otherwise)	2.17	2.17
	(2.26)	(2.26)
Flextime indicator (1 if adopted flextime, 0 otherwise)	−2.08	—
	(−1.92)	
Nonsupervision indicator (1 if do not supervise anyone, 0 otherwise)	—	2.23
		(1.74)
Schedule control indicator B (1 if high control over work done face to face, 0 otherwise)	−1.63	−1.63
	(−1.72)	(−1.72)
Schedule control indicator D (1 if high control over location specific work, 0 otherwise)	—	2.25
		(2.38)
Prefer to work with team than solo (5-point scale: 1 = strongly disagree to 5 = strongly agree)	−1.64	−1.64
	(−2.66)	(−2.66)
Work computer availability indicator (1 if can borrow computer from work, 0 otherwise)	3.21	3.21
	(2.86)	(2.86)
Family orientation indicator (1 if an extra hour would be spent with family, 0 otherwise)	—	2.08
		(2.16)
Family and friends more important than work (5-point scale: 1 = strongly disagree to 5 = strongly agree)	1.98	1.98
	(2.93)	(2.93)
Model statistics		
Log-likelihood at zero		−71.41
Log-likelihood of market-share		−64.48
Log-likelihood at convergence		−31.08
ρ^2		0.56
ρ^2 (adjusted)		0.47
Total number of observations	65	100.00%
Number who chose:		
Never telecommute	34	52.31%
Infrequently telecommute	10	15.38%
Frequently telecommute	21	32.31%

[a] Coefficients for the choice never to telecommute were normalized to zero for this estimation.

more prevalent than others, accounting for five variables. This compares with two each for household, transportation, and personal attitude and awareness variables.

Household Attributes

The coefficient for income per capita was positive for both frequent and infrequent telecommuting. This is as expected and agrees with the sign of other variables, like the home-office indicator and vehicles per capita reported for San Diego, which capture an income effect. The second household variable that was statistically significant was the small-children indicator. The coefficient was positive for both frequent and infrequent

telecommuting, indicating households with small children present are more likely to choose telecommuting. This result is similar to, and agrees in sign with, the indicator for women with small children present in the household that was significant in the San Diego model.

Transportation and Travel Behavior Attributes

The departure time change indicator discussed in the San Diego model was also significant and of the same sign in the FTB model. In this model the coefficients were significant for both the frequent and infrequent options, whereas in the San Diego model only the coefficient for infrequent telecommuting was significant. As mentioned previously, this may indicate an underlying dissatisfaction with the commute that telecommuting can resolve. For some, the need for commute flexibility may be occasional only, as in response to a child-care crisis. For others, it may be a more permanent source of dissatisfaction as in a commute lying along a route that is always severely congested. The flextime-indicator coefficient was negative for infrequent telecommuting, which indicates that individuals who have adopted flextime may use that work option to adjust to nonroutine time demands in preference to occasional telecommuting.

Work Attributes and Attitudes Toward Work

The nonsupervision indicator that reflected a person not supervising other workers was significant in this model instead of the indicator for supervision of supervisors that was important in the San Diego model. In this case, nonsupervisors showed a preference for frequent telecommuting. This finding is interesting, especially as it highlights (by omission) the relative unsuitability for telecommuting of line-supervision jobs in comparison to middle and upper management on one hand and nonsupervisory positions on the other.

Like the San Diego model, a high degree of control over work was found to be an important ingredient in the choice of telecommuting frequency. Unlike San Diego, this control factor was expressed both positively and negatively. A high degree of control over location-specific work led to a choice of frequent telecommuting. In the FTB model control over remote work was not significant, but control over work done face to face was. The coefficient for control over work done face to face was negative, for both frequent and infrequent telecommuting. It is quite possible that face to face contact, for people with a high degree of control over that aspect of work, may comprise a substantial portion of the work performed. Supervisory and managerial positions often fall into this category, as do many customer service positions.

Not surprisingly, a preference for working as a team rather than alone resulted in a disinclination for infrequent or frequent telecommuting. Equally predictable was the coefficient for the indicator of the ability to borrow a workplace computer—positive for both frequent and infrequent telecommuting.

Personal Attitudes and Awareness

The coefficients of these two variables are at odds with similar coefficients for the San Diego model. For the FTB model, the coefficient of the family orientation indicator was positive for the frequent telecommuting choice. In the San Diego model the coefficient of this variable for this choice was negative. In addition for the FTB data, the more an individual felt friends and family were more important than work, the more telecommuting both frequently and infrequently was preferred. It is possible that this contradiction between models is explained, at least in part, by the greater number of female respondents from the FTB than from San Diego (70.0% versus 53.1%, respectively). In both models

the presence of small children in the home increased the probability of choosing to telecommute. This could suggest that home-based telecommuting represents a greater conflict between work and family obligations for women than for men.

Constants

The constant coefficients for this model were negative like those for the San Diego data. As in the San Diego model, the negative sign of the constant coefficients indicates that for both the choice to telecommute infrequently and the choice to telecommute frequently, the mean of unobserved effects is negative. This is reasonable because similar, though perhaps not identical, structural barriers to telecommuting can be expected within both the FTB and the City of San Diego.

Model Statistics

The model was estimated using 65 complete observations out of the 90 total available data records. The null hypothesis that all coefficients are zero (i.e., all telecommuting frequencies are equally likely to be chosen) can be rejected with greater than 99.9% confidence ($\chi^2 = 80.66$, df = 13). The null hypothesis that all coefficients, except those of the alternative-specific constants, are zero (i.e., the explanatory variables contribute nothing because the choice probabilities are entirely defined by the market share of the choice alternatives) can also be rejected with greater than 99.9% confidence ($\chi^2 = 66.8$, df = 11).

The ρ^2 value for the model was 0.56, and ρ^2-adjusted (adjusted for the number of coefficients) was 0.47. Again, these values are considered quite respectable.

PUBLIC UTILITIES COMMISSION MODEL

The PUC model estimation results are contained in Table 4. Variables from three of the four categories – household, transportation, and work – were found to be significant in explaining the choice of telecommuting frequency among Public Utilities Commission employees. In this model, as in the previous two, work-related attributes were most abundant, accounting for five variables. This compares with two household attribute variables and three variables describing transportation and travel behavior. No personal attitudes and awareness variables were found to be significant for this model.

Household Attributes

As in the San Diego model, the coefficient for the number of people in the household was found to be positive for the choice to telecommute frequently. As noted previously, this may represent a desire for increased work/commute flexibility in the face of increasingly complex family interactions. The coefficient of the indicator for the special condition of women with infants under 2 years old present in the household was positive and significant only for the choice to telecommute infrequently. This may indicate a desire in this socio-economic group to telecommute as a flexible, occasional means of attending to child-related illnesses and other emergencies. This is consistent with the coefficient of the indicator variable in the San Diego model for women with children under 5 years old present in the household. It is also similar to, and agrees in sign with, the indicator for small children that was significant in the FTB model.

Transportation and Travel Behavior Attributes

The coefficient for vehicles per licensed driver in the household was positive for infrequent telecommuting. This is similar to the results in the San Diego model for vehicles per capita where the sign was positive for both infrequent and frequent telecommuting. The lack of a significant coefficient in the PUC model for frequent telecommuting may

TABLE 4
Multinomial Logit Estimation Results of the Choice of Telecommuting Frequency for Public Utilities Commission Employees

Independent variable	Coefficient estimate (*t*-statistic) associated with each telecommuting frequency dependent variable[a]: Infrequently	Frequently
Constant	−3.97	−8.61
	(−3.03)	(−2.44)
Number of people in household	–	1.25
		(2.01)
Female with infants indicator (1 if female and children under 2 present in household, otherwise 0)	2.76	–
	(2.06)	
Vehicles per licensed driver in household	2.02	–
	(2.42)	
Mode to work change indicator (1 if mode of work trip has changed in the past year, 0 otherwise)	−1.69	–
	(−2.02)	
Willing to reduce driving to improve transportation and air quality (5-point scale: 1 = strongly disagree to 5 = strongly agree)	–	3.35
		(2.14)
Length of time in present occupation	0.11	0.11
	(2.77)	(2.77)
Length of time with present employer	−0.12	–
	(−2.21)	
Schedule control indicator C (1 if high control over work done remotely, 0 otherwise)	3.92	–
	(3.77)	
Work computer availability indicator (1 if can borrow computer from work, 0 otherwise)	–	4.71
		(2.84)
Am a workaholic (5-point scale: 1 = strongly disagree to 5 = strongly agree)	−1.42	–
	(−1.74)	
Model statistics		
Log-likelihood at zero		−71.41
Log-likelihood of market-share		−58.98
Log-likelihood at convergence		−34.93
ρ^2		0.51
ρ^2 (adjusted)		0.43
Total number of observations	65	100.00%
Number who chose:		
Never telecommute	37	56.92%
Infrequently telecommute	22	33.85%
Frequently telecommute	6	9.23%

[a] Coefficients for the choice never to telecommute were normalized to zero for this estimation.

be due to the different formulation of the variable, the smaller sample size or an inherent difference in the importance of vehicle ownership between City of San Diego employees and the San Francisco-based PUC employees.

One interesting variable present in the PUC model, but not the San Diego or the FTB model, is the indicator for recent change of mode to work. The coefficient of this variable, which captures whether an individual has changed method (i.e., bus, carpool, drive alone, etc.) of getting to work in the past year, was negative for infrequent telecommuting. This suggests that the change has either adjusted an unsatisfactory commute so that there is currently less incentive to change work/commute option (i.e., the never-telecommute option is more likely to be chosen), or that the adjustment was insufficient

to make major changes in commute satisfaction (i.e., frequent telecommuting is more likely to be chosen as a work/commute option). Another variable appearing only in the PUC model is willingness to reduce driving to improve transportation and air quality. As expected, the more willing to reduce driving, the more frequently telecommuting occurs.

Work Attributes and Attitudes Toward Work

The coefficient for length of time in present occupation was positive for both frequent and infrequent telecommuting, whereas the coefficient for length of time with present employer was negative for infrequent telecommuting. These coefficients together illustrate some of the complex and sometime contradictory workplace attributes that affect the choice to telecommute. The positive coefficients for length of time may represent a human capital effect. They could indicate that as a person pursues one line of work and masters its skills over time, the ability to work alone productively increases, making telecommuting an increasingly desirable choice. The negative coefficient for time with present employer may reflect a dual-career track. On one hand, as time goes by an individual may gravitate to positions of trust in high-autonomy, technical, or professional specializations. On the other, as time passes an individual may move into management, which, at least at the line supervision level, would require more face to face work and generate the requirement to co-locate with those being supervised. Over time the choice to telecommute may become a dichotomy (other things being equal), either never or frequently, with little middle ground. The complexity of interaction of work-related variables suggests that additional study and testing in this area would be useful.

Like the San Diego model, the coefficient of the indicator for high control of work done remotely was positive for infrequent telecommuting. Unlike San Diego, the coefficient for frequent telecommuting was not significant. The difference may result from a difference between San Diego and PUC respondents in the types of jobs done remotely, or in the amount of remote work as a portion of the work day.

The coefficient of the indicator for ability to borrow a work-place computer was positive as expected. This is similar to the FTB model. For PUC data, however, this coefficient was significant only for frequent telecommuting; in the FTB model, the coefficient was significant for both infrequent and frequent telecommuting. The difference may reflect greater difficulty in nonroutine computer borrowing at PUC, or may reflect differing distributions of computer equipment at the two agencies.

An interesting variable whose coefficient was negative for infrequent telecommuting measured how much individuals considered themselves workaholics. The sign of this coefficient suggests a preference for routine and structure among these individuals that can be met either by working exclusively at the office or frequently at home, but which infrequent telecommuting, especially on a nonscheduled basis, would not allow.

Constants

The constant coefficients for this model were negative like those for the San Diego and FTB data. As in the two previous models, the negative sign of the constant coefficients indicates that for both the choice to telecommute infrequently and the choice to telecommute frequently, the mean of unobserved effects is negative. This is reasonable because similar, though perhaps not identical, structural barriers to telecommuting can be expected at the Public Utilities Commission as are found at the City of San Diego and the Franchise Tax Board.

Model Statistics

The model was estimated using 65 complete observations out of the 90 total available data records. The null hypothesis that all coefficients are zero (i.e., all telecommuting frequencies are equally likely to be chosen) can be rejected with greater than 99.9% confidence ($\chi^2 = 72.96$, df = 12). The null hypothesis that all coefficients, except those of the alternative-specific constants, are zero can also be rejected with greater than 99.9% confidence ($\chi^2 = 48.1$, df = 10).

The ρ^2 value for the model was 0.51, and ρ^2-adjusted (adjusted for the number of coefficients) was 0.43. These values are comparable to those for the other two models.

Finally, to visually compare the differences among the model estimation results for the San Diego, Franchise Tax Board, and Public Utilities Commission data sets, Table 5 presents a summary of significant variables. This table suggests that the differences among the three data samples, and consequently telecommuting behavior in the three organizations, is substantial. We statistically test for such differences below.

Model Specification Tests

Two sets of specification tests were performed on the models estimated. The purpose of the first set of tests was to verify the reasonableness of the assumption that three separate models should be estimated: one for San Diego, one for FTB, and one for PUC. The alternatives would be to estimate one model for data pooled from all three sources, or to estimate one model for San Diego and a pooled model for combined FTB and PUC data. The second set of specification tests was performed to verify that the multinomial, as opposed to the nested, logit model structure was valid. This was done by calculating test statistics to determine if the Independence of Irrelevant Alternatives (IIA) property of simple logit models was violated.

To test whether the data should be pooled, a likelihood ratio test was performed that compares the log-likelihood values of the unrestricted models (the three estimated separately) to values for models that were restricted by estimation on pooled data [1].

The first test performed was to determine if the San Diego model should be estimated separately from a pooled model for FTB and PUC data. To accomplish this, a model was estimated for data pooled from all three sources using the variables of the San Diego model shown in Table 2. A second model was estimated for pooled FTB and PUC data using the San Diego variables. The log-likelihood of these two models plus the San Diego model shown in Table 2 were combined in a likelihood ratio test to give a χ^2 value of 38.90 with 22 degrees of freedom. This means that the null hypothesis that San Diego data should be pooled with FTB/PUC data can be rejected with 99.0% confidence.

In a similar fashion, the null hypothesis that FTB and PUC data should be pooled was examined. To calculate the test statistic, a pooled FTB/PUC model was estimated using FTB variables. A model was also estimated for PUC data using FTB variables. The log-likelihood at convergence for these two models was combined with that for the FTB model shown in Table 3 to give a χ^2 value of 58.40 with 13 degrees of freedom. This means that the null hypothesis that FTB data should be pooled with PUC data can be rejected with greater than 99.9% confidence. Taken together, these tests validate the decision to estimate a separate model for each source of data.

The second specification test was performed to validate the choice of a multinomial, or simple, logit structure versus a nested structure. With a multinomial structure, the choice of telecommuting frequency is assumed to be made between three independent, competing alternatives: never telecommute, telecommute infrequently, and telecommute frequently. The nested structure addresses the possibility that telecommuting alternatives (i.e., frequently and infrequently) may have shared, unobserved effects. If shared, unobserved effects are present and a simple, nonnested structure is used, the assumption of independently, identical distributed (IID) error terms made during the derivation of the

TABLE 5
Comparison of Significant Variables across Subsamples

Variable	Data source: San Diego	Franchise Tax Board	Public Utilities Commission
Household attributes			
Number of people in household	F		F
Income per capita in household		I, F	
Small children indicator (1 if children under 5 present in household, 0 otherwise)		I, F	
Female with small children indicator (1 if female and children under 5 present in household, 0 otherwise)	I		
Female with infants indicator (1 if female and children under 2 present in household, 0 otherwise)			I
Home office indicator (1 if have home office space, 0 otherwise)	F		
Vehicles per licensed driver in household			I
Vehicles per capita in household	I, F		
Automobile is status symbol (5-point scale: 1 = strongly disagree to 5 = strongly agree)	F		
Transportation/travel attributes			
Departure time change indicator (1 if work trip departure time has changed for personal reasons in the past year, 0 otherwise)	I		
Mode to work change indicator (1 if mode of work trip has changed in the past year, 0 otherwise)			I
Willing to reduce driving to improve transportation/air quality (5-point scale: 1 = strongly disagree to 5 = strongly agree)			F
Work-related attributes			
Hours worked in a 2-week period, including paid and unpaid overtime	F		
Unpaid overtime indicator (1 if worked unpaid overtime in the past 6 months, 0 otherwise)	I		
Work at home indicator (1 if took work home in the past 6 months, 0 otherwise)	I		
Flextime indicator (1 if adopted flextime, 0 otherwise)		I	
Supervision indicator (1 if supervises other supervisors, 0 otherwise)	I, F		
Nonsupervision indicator (1 if do not supervise anyone, 0 otherwise)		F	
Clerical occupation indicator (1 if occupation is clerical or administrative support, 0 otherwise)	I, F		

TABLE 5
(Continued)

Variable	Data source: San Diego	Franchise Tax Board	Public Utilities Commission
Full-time work indicator (1 if worked full-time instead of part-time in the past two years, 0 otherwise)	F		
Remote work indicator (1 if more than 24 hours/week is work done remotely, 0 otherwise)	I		
Schedule control indicator B (1 if high control over work done face to face, 0 otherwise)		I, F	
Schedule control indicator C (1 if high control over work done remotely, 0 otherwise)	I, F		
Schedule control indicator D (1 if high control over location specific work, 0 otherwise)	F	F	I
Prefer to work with team than solo (5-point scale: 1 = strongly disagree to 5 = strongly agree)		I, F	
Work computer availability indicator (1 if can borrow computer from work, 0 otherwise)		I, F	F
Productivity difficult in work place (5-point scale: 1 = strongly disagree to 5 = strongly agree)	I, F		
Length of time in present occupation			I
Length of time with present employer			I
Am a workaholic (5-point scale: 1 = strongly disagree to 5 = strongly agree)			I
Personal attributes			
Telecommuting familiarity indicator (1 if knows a telecommuter, 0 otherwise)	I, F		
Lack of self-discipline (5-point scale: 1 = strongly disagree to 5 = strongly agree)	I, F		
Family orientation indicator (1 if an extra hour would be spent with family, 0 otherwise)	F	F	
Family and friends more important than work (5-point scale: 1 = strongly disagree to 5 = strongly agree)		I, F	
Satisfied with life (5-point scale: 1 = strongly disagree to 5 = strongly agree)	F		

I = coefficient significant for choice of infrequent telecommuting; F = coefficient significant for choice of frequent telecommuting.

multinomial logit model will be violated. IIA problems will arise if this assumption is violated. The grouping of telecommuting alternatives into a lower nest eliminates the problem of shared, unobserved effects because the logit probabilities are based on differences in alternative utilities, therefore any shared (common) effects will cancel in the subtraction. The nested structure does not necessarily imply a sequential decision process, it is merely an approach to address possible error term correlation.

If the IIA property holds, then a multinomial logit structure for estimating the choice of telecommuting frequency is appropriate. To determine if possible IIA violations are present, an approximate likelihood ratio test used by McFadden, Tye and Train [8] with a correction proposed by Small and Hsiao [15] was conducted on each of the three models shown in Tables 2, 3, and 4. To calculate the test statistic, a restricted model was generated for each of the three sources of data. In this restricted model, one of the three choice alternatives was removed from the choice set of each of the three unrestricted models. The restricted models did not contain any alternative-specific variables for the choice removed from the corresponding unrestricted model. Also, observations that selected the alternative excluded in the restricted models, were excluded from the estimation of the restricted models.

For the San Diego model, the IIA tests gave a χ^2 value of 6.12 with 16 degrees of freedom. This means that the null hypothesis that the IIA property holds cannot be rejected with more than 1% confidence. For FTB the χ^2 value was 5.17 with 9 degrees of freedom. This means that the null hypothesis that the IIA property holds cannot be rejected with more than 18% confidence. For PUC the χ^2 value was 2.66 with 6 degrees of freedom. This means that the null hypothesis that the IIA property holds cannot be rejected with more than 15% confidence.

In no case can the null hypothesis that the IIA property holds be rejected with greater than 18% confidence. This strongly suggests the appropriateness of the multinomial logit structure used in this analysis. This finding is confirmed by the results of an early model estimation in which a nested structure was used for an analysis of data pooled from all three sources. The logsum calculated from the coefficients of the lower nest was very close to 1.0 indicating that a nested structure was unnecessary.

Summary and Conclusions

This study analyzed data collected from a survey of City of San Diego, Franchise Tax Board, and Public Utilities Commission employees. A total of 809 usable survey responses were received and used in the analysis: 629 from San Diego, and 90 each from the FTB and PUC. Summary statistics for the data were presented and discussed. A multinomial logit model of the choice of frequency of telecommuting was proposed and estimated, and the results discussed. Specification tests to verify the model structure were performed. A number of important conclusions and findings from this study are discussed below.

One important conclusion is that models for San Diego, FTB, and PUC should be estimated separately. This apparent lack of model transferability points up the need to identify variables to describe attitudes that tend to differentiate one organization from another. These could be attributes such as size, geographic location, managerial structure, age, and industry.

In a similar vein, the need for separate models suggests that differing degrees of experience, both individually and organizationally, with telecommuting will result in differing choice dynamics for individuals considering telecommuting decisions. In other words, choice behavior varies depending on the degree of experience with telecommuting.

Based on the function of these agencies as a field test of the survey, as discussed earlier, a far greater percentage of FTB and PUC employees in our samples telecommute than San Diego employees: 45.5%, 41.6%, and 16.4%, respectively. In addition both FTB and PUC have a strong formal, agency-wide telecommuting program. In these agencies there is a very high level of awareness of and participation in telecommuting, and an existing organizational policy to encourage telecommuting in appropriate circumstances. The City of San Diego has a telecommuting program, but it is not as widely implemented or as well-known as those at the other two organizations.

This research suggests that gender-based cultural expectations about the work and family roles of men and women may be important to the choice of telecommuting frequency. One factor that may help account for the inability to pool FTB and PUC data is the striking difference in gender of respondents from the two agencies. At the FTB, 70.0% of respondents were female, compared to only 34.8% of PUC respondents. The manifestation of gender-based cultural expectations is suggested by the absence of any personal attitude attributes in the PUC model, compared to the presence of only family-oriented personal attributes in the FTB model.

Turning to model estimation results, as expected in explaining the choice of telecommuting frequency, a variety of attributes were significant. These attributes, also not surprisingly, varied substantially from one model to the next. Among the types of variables considered, work-related variables were well represented in each model: 10 of 21 for San Diego, 6 of 12 for the FTB, and 5 of 11 for the PUC. This indicates the relative importance of these attributes in the choice of what is after all a work option. The number and apparent complexity of interaction of these variables suggests a need for additional research to better identify key attributes in this area.

Of the statistically significant variables, only a few were found to be present in more than one model. Variables that were found in more than one model, and thus considered to have the most general explanatory power for the choice of frequency of telecommuting, were the presence of small children in the household (found as part of variable formulations present in all three models), the number of people in the household (found in two models), gender of respondent (found as part of variable formulations in two models), number of vehicles in the household (found as part of variable formulations in two models), whether respondent recently changed departure time for personal reasons (found in two models), degree of control over scheduling of different job tasks (found in three variables in all three models), supervisory status of respondent (found in two models), the ability to borrow a computer from work if necessary (found in two models) and a family orientation (found in two models). Variables unexpectedly not significant were distance to work, time to work, a recent departure time change in response to congestion, managerial or professional occupation, and the amount of work time spent in face to face contacts.

It is extremely interesting that neither the distance to work, nor the time required to commute was statistically significant in any of the three models. The literature reviewed on this topic contained somewhat contradictory findings. On one hand, length of commute was found to predict participation in telecommuting programs. In some cases, a longer than average commute is an explicit selection criterion for demonstration program participants. Once part of a program, however, length of commute was not found to predict the frequency of telecommuting for program participants [see 13]. The stated preference modeling efforts cited in the introduction also found that people with longer or more stressful commutes were more likely to want to telecommute. Taken as a whole, this

implies that some measure of length or stress of commute should be positive for both the choice to telecommute infrequently and to telecommute frequently.

One explanation for this counter-intuitive finding is that work or other constraints may be so prevalent that even those people who are well-motivated to telecommute because of onerous commutes cannot arrange the opportunity to adopt the work option. This dovetails with the conceptual framework proposed by Mokhtarian and Salomon [11]. Another possibility is that commute stress is experienced as just one component of overall life stress. Only if overall life stress is high, would a reduction in commute stress be a significant predictor of the choice to telecommute.

This study suggests a need for research in several areas. The first is a need to collect data that includes a better sampling of full-time telecommuters. Of the 809 total usable observations in the data set, only 4 respondents (all from the FTB) telecommuted from home 5 days/week. In addition, only 7 respondents (1 from San Diego and 6 from the FTB) telecommuted 3-4 days/week. It is acknowledged that the collection of such data raises a series of complex sampling issues. Even though the consensus of opinion in many quarters is that full-time, home-based telecommuting will never be the dominant mode for this work option, however, the ability to draw conclusions regarding the choice of frequency to telecommute is hampered if data on one of the extremes of choice is too sparse.

It is further concluded that there is a need to develop a better understanding of the interaction between commute length, stress, and the choice to telecommute. One cornerstone of public policy interest in telecommuting is its potential to reduce urban congestion and auto-related pollution. In this context, it is important to be able to assess when and if travel-related attributes of choice will motivate commuters to select modes of work or travel other than the traditional single-occupancy vehicle.

Another area of further research identified is to define a series of organizational attribute variables. As discussed above, the inclusion of such variables as organization size and geographic location may allow model transferability from one organization to another. Yen and Mahmassani [17] are developing integrated models of individual and organizational adoption of telecommuting, which may prove fruitful in this regard.

And finally, this research provides new information on the interplay of constraints and motivations that surround the individual's decision to telecommute. Only recently have sufficient numbers of people experienced the telecommuting work option so that an effort to collect revealed preference data would yield sufficient information to allow the estimation of empirically based models. This leads to the last perceived research need, which is in some ways the most obvious and fundamental. There is a great need simply to collect additional data from different locations on the revealed choice to telecommute, in a form that will allow continued empirical development of behavior-based demand models. With the number of telecommuters in this country now in the millions, the prospects are very good that a well-designed survey effort with a rigorous sampling strategy would yield data suitable for use in such modeling efforts. Further, it is important to replicate studies on a temporal as well as a spatial basis. It may be that the early adoptors of telecommuting that have been surveyed to date will differ from later mainstream adoptors in their motivations to telecommute and in the role of constraints and facilitators on their decision process.

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