Stated Preference Approach to Modeling the Adoption of Telecommuting

ADRIANA BERNARDINO, MOSHE BEN-AKIVA, AND ILAN SALOMON

Many researchers have suggested the potential use of telecommuting as a substitute for travel to reduce traffic congestion, energy consumption, and air pollution. The effectiveness of this working arrangement as a strategy to address these policy issues, however, will depend on the level of adoption and on the impacts of usage on individuals' travel behavior. This paper discusses the process of individuals' adoption of telecommuting, given that the alternative is made available by the employer. A review of the relevant research concerning individuals and the process of adoption of telecommuting is presented. On the basis of the state of the art, a framework to model this process is proposed. An empirical study conducted to demonstrate the proposed framework is described. The implications of the main findings of this study policy design are analyzed and directions for further research are suggested.

Many researchers have suggested the potential use of telecommuting as a substitute for travel to reduce traffic congestion, energy consumption, and air pollution. This expectation is derived from four major trends: innovations in the area of information technology (IT), the increasing social cost of transportation, the transition to the "information economy," and changes in individuals' lifestyles.

Developments in information technology have significantly reduced the costs of terminal equipment and increased their capabilities. The introduction of fiber optics and microwaves represents a potential growth in terms of capacity and speed of data transmission. Many IT applications are now being developed to improve individuals' and groups' interactions, relaxing physical and temporal constraints on activity performance.

These innovations significantly reduce coordination costs, leading organizations to a restructuring process that continues to involve more value-added partnership and ad hoc teamwork instead of rigid, hierarchical structures. Consequently, the accessibility of employees through a communication network becomes much more important than their physical presence in the office, which may encourage the adoption of telecommuting.

Simultaneously, policy makers' interest in telecommuting is significantly growing, as shown by the recent, increasing level of investments made in demonstration projects. In addition to its potential to reduce private and social transportation costs at a low investment level by government, telecommuting can also address issues such as regional development, opportunities for disabled persons, and emergency preparedness, among others.

A. Bernardino and M. Ben-Akiva, Department of Civil and Environmental Engineering, Massachusetts Institute of Technology, 77 Massachusetts Avenue, Cambridge, Mass. 02319. I. Salomon, Department of Geography, Har Hazoffim, Hebrew University, Jerusalem, Israel.

Nevertheless, some transportation and telecommunications planners have questions still to be answered. There are indications that telecommuting is gaining ground in the United States and Europe. However, the assessments of the current number of telecommuters, as well as the current forecasts of telecommuting and its impacts in terms of demand for infrastructure and services, vary widely. The variations are due to inconsistent definitions and inappropriate forecasting techniques as well as different assumptions about the nature of the behavioral responses to the availability of this option.

The objective of this study is to take one further step in the direction of understanding telecommuting, beyond most efforts conducted to date. This study involved the development of a model of the decision to adopt telecommuting by the individual.

The remainder of this paper is organized in four sections. The section on Previous Research presents a review of the research concerning individuals and the process of adopting telecommuting. The section on Modeling Framework proposes a framework to model the adoption process. The Pilot Study and Conclusions sections describe and discuss an empirical study conducted to demonstrate the proposed framework.

PREVIOUS RESEARCH

Research relevant to the process of adopting telecommuting by the individual can be broadly divided into two main streams: one that emphasizes the sociological aspects of this new working arrangement and another that focuses on the impacts of telecommuting on travel behavior.

Sociological research describes some characteristics of individuals, their households, and their environments that may be relevant to the adoption of telecommuting, as well as the impacts of adoption of this working arrangement on telecommuters. Travel behavior research analyzes individuals' patterns of usage of the transportation system once telecommuting is adopted.

Characteristic of the research on telecommuting is the fact that studies fall short of taking a comprehensive perspective, usually remaining within traditional disciplinary lines. The main studies in both of the two major directions of research follow.

Sociological Research

Sociological research can be further divided into characterization of telecommuters profiles and impacts of telecommuting adoption on individuals.

Characterizations of Telecommuters' Profiles

Olson (*1*), Olson and Primps (*2*), and Pratt (*3*), based on analyses of work-at-home pilot programs of various organizations, identified telecommuters as (a) male managers or professionals who perceive more value in part-time integration of work and family than career advancement, (b) full-time female clerical workers who have child-care responsibilities or are seeking to increase income by reducing personal expenses, and (c) managerial and professional mothers who want to nurture young children without completely falling behind in their careers.

Kraut and Grambsch (*4*), based on a statistical analysis of 1980 census work-at-home data, observed that telecommuters were likely to belong to groups that experience social or physical constraints to their mobility. This finding, however, may not be representative of actual telecommuters because the definition of work-at-home in the census is much broader than that of telecommuting.

Bailyn (*5*), analyzing an organization in the United Kingdom, found that telecommuters tend to value interesting work, family life, and leisure time more than pursuing a career. Their counterparts, the office workers who do not telecommute, are more career oriented and value status, prestige, and success more than family life, flexibility, and merely maintaining skills.

The author also identified a "traditional" home-based orientation among female telecommuters, who were more interested in home and family than in career goals. Male telecommuters, on the other hand, perceived some value in work but had given priority to their preferred lifestyle and a balanced life over career and achievement.

Christensen (*6*) and Olson (*7*) proposed that only managers and professional workers will decide to work at home on the basis of their personal preferences. Clerical employees will work under this arrangement due to family demands or to low income levels.

These studies lead to the hypotheses that alternative lifestyles and socioeconomic constraints may be significant factors in the decision to adopt telecommuting. They also suggest the hypothesis that telecommuters will either be in the position of bargaining for their working arrangement or, having no alternative, being eventually exploited.

Impacts of Adopting Telecommuting on Individuals

Telecommuting may be quite a radical change from the routine work patterns. Work is the main activity around which other activities are organized. Thus a change in the work arrangement may have far-reaching impacts on the total activity patterns of individuals and their households. The expected impacts on individuals are likely to affect their likelihood of adopting telecommuting. Moreover, the likelihood that others will adopt telecommuting is also a factor that may influence this decision.

Through interviews with supervisors, Pratt (*3*) identified some categories of white collar employees who had either returned to the office full time or stopped working after rejecting home telework. The main categories identified were (a) single men and women whose social life centered on office contacts, (b) handicapped workers who found it physically impossible to work long hours at a terminal, (c) workers whose families objected to their presence at home, (d) individuals who were not self-disciplined enough to perform their jobs without supervision, and (e) workers whose off-site productivity could not be easily measured by their supervisors.

In a study evaluating changes in home computer use, Vitalari et al. (*8*) concluded that computers at home were used mostly for work and had the impact of decreasing the time spent with family and friends and increasing the time spent alone, leading to social isolation. Kraut (*9*) concluded that the experience with computer owners to date shows that individuals use home computers to work extra, generally nonpaid, hours. Bailyn (*5*) suggests that both "workaholism" and exploitation of workers by organizations may be observed in telecommuting.

Reviewing Christensen's work, Bailyn also pointed out the findings that telecommuting and child care can be combined only with difficulty. When adopting this option, male professionals experienced improvements in family life, whereas the opposite was experienced by female clerical workers with replaceable skills. Olson (*7*) also confirmed that women working at home felt constant stress and pressure from both work and family demands, with little time left for themselves or for leisure.

In a review of four telecommuting experiments conducted in Japan, Spinks (*10*) identifies the main work-related problems to be a lack of concise job descriptions as well as a lack of time-management and self-supervisory skills. Most individuals agreed that flexibility to work according to ones' biorhythm was more productive and generated a greater sense of creativity, but a lack of motivation in the initial stages led to longer working hours closer to deadlines.

An interesting aspect noted in one of the experiments was that, for cultural reasons, some individuals did not feel comfortable about the possibility of having the whole family together frequently.

The absence of a commute was positively regarded by most telecommuters, as well as the possibility of working in casual clothing. However, by working and living under the same roof, some telecommuters never experienced the feeling of being completely "off duty."

These findings lead to the conclusion that it is necessary to consider job and commuting characteristics, as well as individuals' personalities, attitudes, and cultural values, when evaluating the potential telecommuting adoption.

Telecommuting, Travel Behavior, and the Transportation System

Salomon (*11*), Nilles (*12*), and Mokhtarian (*13*) have discussed the expected impacts of telecommuting on travel behavior, and the main hypotheses formulated from these discussions can be classified as short-term or long-term hypotheses.

The most immediate expected result is a reduction in the number of peak-hour trips due to the reduction of commutes. A shift of trip time to off-peak hours is also expected. Nonwork trip destinations may be expected to be closer to home, allowing for a shift to nonmotorized transportation modes. On the other hand, carpools may be interrupted, requiring individuals to drive alone and generating more trips as a result. A reassignment of activities may be observed in tele-

commuters' households, in which the responsibility for household-related trips is transferred to regular commuter members. The elimination of the work trip may also disrupt trip chains.

Pendyala et al. (*14*), analyzing data from the State of California Telecommuting Pilot Project, found significant reductions in commute trips, peak-period trips, total distance traveled, and freeway miles due to telecommuting. It was also noted that telecommuters chose nonwork destinations closer to home and exhibited a contracted "action space" on both telecommuting and commuting days. Nonwork trips showed similar temporal patterns on both telecommuting and commuting days.

Hamer et al. (*15*), in an evaluation of the telecommuting pilot project conducted in the Netherlands, found that teleworking can be fairly successful in reducing the total travel time of teleworkers. The authors observed a significant reduction in peak-hour traffic by car as well as a decrease in the number of trips teleworkers made for other purposes. A reduction in the number of trips made by household members was also observed, contrary to initial expectations.

Many long-term effects may be expected due to the adoption of telecommuting. A reduction in the level of automobile ownership may be expected. Changes in job locations may be observed. Changes in residential location may occur, which may or may not lead to an offset of the telecommuting benefits in terms of energy consumption and pollution reduction. Research indicates, however, that at least in the short run, telecommuting presents travel impacts that are favorable enough to justify further interest in its potential as a measure for travel demand management.

Moreover, Nilles (*16*) hypothesized that telecommuting can be structured based on telework centers, so that it does not influence residential location decisions that result in net long-term increases in travel. From an analysis of the California Telecommuting Pilot Project, Nilles indicated that results support the hypothesis that telecommuting does not increase urban sprawl and that telecommuting does produce net reductions in household travel.

Summary

The travel behavior research demonstrates that once telecommuting is adopted, at least in the short run, it has positive impacts on the transportation system.

Sociological research, on the other hand, shows that lifestyle choices and socioeconomic constraints influence the decision to telecommute. It also makes clear that aspects of individuals' personal and professional environments should be considered in the process.

Nevertheless, none of the pieces of research reviewed try to quantify the magnitude of the impact of each factor on the adoption process in a way that may be useful for policy development. This paper represents an initial movement toward filling this gap in understanding the process of adoption of telecommuting by individuals.

MODELING FRAMEWORK

The framework presented in Figure 1 incorporates both the organization's and the employees' inputs in the analysis of telecommuting adoption. At the center of the structure are two sequential choices that individuals will make when faced with the option to telecommute: the decision to adopt (or reject) telecommuting and the subsequent decision as to the level of adoption, if they choose to telecommute. The decisions are made against a background that consists of an environment and personal factors. The major elements of this structure are described below.

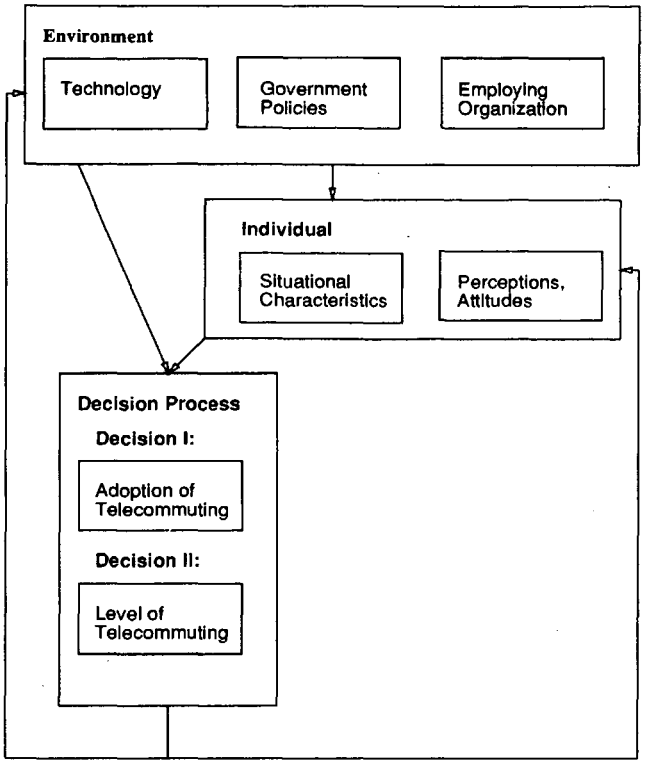

FIGURE 1 Framework for modeling the telecommuting adoption process.

Environment

Individuals act within an environment that includes social, cultural, economic, technological, and institutional characteristics. The environment sets the context within which individuals can choose in terms of options and constraints. The important elements of the environment for the current framework are discussed in sequence.

Technology

Technology can be either a facilitator of or a barrier to telecommuting. Jobs vary in the requirement for interaction with machines and coworkers. Some jobs are not technology intensive, and can probably be performed with a simple telephone. Other jobs may require that workers have at their disposal some sophisticated (and sometimes expensive) equipment necessary for their routine performance. The supply of

such technologies at the individuals' home raises a number of questions regarding technological feasibility, costs, and other administrative issues.

Government Policies

Governmental entities are initiating policies to reduce transportation's social costs and to encourage organizations to adopt programs to decrease the number of trips made by their employees. In some areas, these policies include an extra bonus for trip reductions obtained by telecommuting. By using these types of regulatory devices, government can exert some influence on the level of adoption of telecommuting. On the other hand, other government agencies are involved in formulating policies designed to protect workers; such policies may not be consistent with those encouraging telecommuting.

Employer

The employing organization's decision to make telecommuting available is a necessary condition for adoption to take place. This decision is a function of the organization's characteristics and of managers' perceptions and attitudes.

Relevant organization characteristics are the composition of the labor force, organizational costs, and organizational structure. The characteristics of the labor force may have an impact not only on the decision to offer telecommuting as an option, but also on the characteristics of the proposed program. It may be expected, for example, that programs offered to professional workers will be more flexible than those offered to clerical employees.

Organization costs may also be relevant to the adoption process. Significant savings may be obtained by reduced requirements of office and parking space. Telecommuting may also decrease absenteeism, sick leave, and turnover rates, and avoid relocation costs. On the other hand, the costs of implementing and operating a telecommuting program may be prohibitive.

The relevance of the organizational structure to the adoption process refers basically to the level of interaction among individuals, sectors, and departments and to the media used to perform this interaction. Structures that require a high level of interaction may have some difficulty in functioning with telecommuting. However, if most of this interaction is performed by means of telecommunication media, telecommuting may actually be favored.

Managers' perceptions and attitudes affect the organization's position with regard to telecommuting programs. Also, the message sent by the manager to the individual employee affects the way in which the individual preceives the program. There is much evidence that at present, many managers do not support telecommuting because they fail to understand how they can manage a remote work force (*7*). Other managers see a great potential in telecommuting as a measure to increase productivity.

The result of the decision made by the organization is the definition of the working arrangement characteristics. Considering organizational characteristics and managers' attitudes and perceptions, a choice is made about whether to make telecommuting available. Telecommuting, however, is not a single unified arrangement. In fact, the concept includes a wide variety of arrangements with the common characteristics that work is performed at a remote location, and, from a transportation perspective, that travel patterns are altered (*13*). Combinations of the attributes described below characterize the telecommuting programs that may be available to employees and directly influence the adoption decision.

Formality Telecommuting can be an informal arrangement between the employer and the employee, or a formal agreement. Some organizations currently institutionalizing telecommuting require employees and supervisors to sign a document on the agreed conditions. Individuals may be more willing to adopt institutionalized arrangements because this formalization may be interpreted as a commitment by the organization. On the other hand, individuals may assume informal arrangements to be more flexible and thus prefer that situation.

Form There are currently two main forms of telecommuting: home-based and remote work centers. In the home-based form, employees work full- or part-time at home and report to a central, remote office. In the remote work center, employees work full- or part-time in a facility that is closer to their home than the office to which they report. At present, there is little documented experience with remote centers. Home-based telecommuting has the advantage of requiring no trips and providing more time for family interaction. On the other hand, remote centers involve a shorter trip than that to the central office, yet providing a buffer between home and office. These centers also provide greater possibilities for socialization as well as better infrastructure and a more well-defined liability context.

Flexibility Some telecommuting programs may have a rigid schedule, determining the number of days or days of the week when telecommuting is allowed. Other programs, however, can be flexible, leaving the schedule for the employee to decide and requiring only that the employee be in the office for one or one half day per week, or be accessible through telephone or computer during certain hours of the day. It is reasonable to expect that employees will prefer more flexible arrangements because flexibility is considered one of the greatest advantages of telecommuting.

Employment Conditions In recent telecommuting experimental projects, mainly those totally or partially funded by the government, it has been suggested that no distinction be made concerning salary and benefits between commuters and telecommuters. This is, however, not necessarily the common practice. In fact, uneven patterns of working conditions have been observed, associated with the scope of telework, organizational purposes for introduction of the program, type of work, and legal aspects of the telework. Telecommuters can be treated as employees or contractors, can be paid by the task or by the hour, and can receive all regular benefits or

none of them. Wage rates can be lower, higher, or the same as those for regular commuters.

Fixed and Operating Costs In both home-based and remote work center telecommuting arrangements, the equipment to be used can be provided by the employee or the employer, or shared between the two parties. Similarly, main operating costs, such as phone bills, may be paid by either one of the parties or otherwise shared.

Liability Questions of liability for the equipment, information, and even the health and safety of the employee must be defined for this new form of working arrangement, particularly for home-based telecommuting. If the employers bear responsibility, then they may require the right of on-site inspection visits.

Individuals' Characteristics

The individuals' characteristics that affect the decision to telecommute include two major elements: the individuals' situational characteristics and the individuals' attitudes and perceptions.

Individuals' Situational Characteristics

Individuals' situational characteristics can be divided into three main groups: job, commuting, and socioeconomic and demographic characteristics.

Job characteristics involve the level of face-to-face interaction demanded by the job and the type of equipment required to accomplish the tasks. These requirements may represent a set of binding constraints to telecommuting.

Commuting characteristics are expected to have a significant influence on individuals' decisions to telecommute. Long commuting times, high levels of congestion, and inconvenience associated with travel may increase the attractiveness of telecommuting.

Socioeconomic and demographic characteristics may also affect the individuals' decision to adopt telecommuting. Gender-based roles, presence of children or adults who need special care, household income, or level of education are expected to contain relevant information and may be used as a basis for market segmentation in forecasting the demand for telecommuting.

Individuals' Perceptions and Attitudes

Individuals' attitudes toward telecommuting in general, and toward specific programs in particular, will influence the decision of whether to consider or to adopt an arrangement. Individuals who do not understand the concept of telecommuting may not perceive it as an viable alternative. Individuals who are career oriented may prefer to work in the central office, while those who are family oriented may prefer to telecommute.

Adopting Telecommuting: Decision Structure

The process of the adoption of telecommuting involves two main decisions by the employee. Based on the working arrangements offered, attitudes, perceptions, and socioeconomic and demographic characteristics, individuals decide whether to telecommute. This is not a daily decision of whether to telecommute or to drive to work, but a long-term choice of accepting certain conditions in exchange for some benefits. Individuals may be able to move in and out of this condition depending on the characteristics of the arrangement.

Once telecommuting is adopted, individuals must decide how much telecommuting to do. In some cases, the intensity of telecommuting may be predetermined and consequently part of the first decision. However, more likely is the situation in which the individual has the flexibility to choose the level of telecommuting, which then becomes a short-term decision.

PILOT STUDY

To obtain some insights into the applicability of the proposed framework, a pilot study was conducted. This study is discussed next.

Data Collection

The pilot study was based on a survey of a group of individuals' preferences concerning hypothetical telecommuting scenarios, that is, stated preference data. The major advantage of this type of data is that scenarios can be elaborated on based on orthogonal design, and models estimated from this data set can elicit information on trade-offs among attributes that may not be clear from revealed preference data. Nevertheless, purely stated preference-based models present many validity problems, originating in the decision protocols adopted by the respondents, imperfect descriptions of alternatives, and omission of situational constraints. They are, therefore, of little or no value for predicting demand, unless they can be validated by revealed preference data. This aspect should be clear during the analysis of the results.

Survey

The survey questionnaire was divided into two parts. Part 1 contained questions about the respondents' job, commuting and demographic characteristics, communication patterns within the organization, the availability and characteristics of the telecommuting program in the respondent's organization, respondent's attitudes towards telecommuting, and perceptions of main barriers to a broader adoption within the organization. Part 2 presented a series of telecommuting programs and asked the respondents about their willingness to telecommute if each one of those programs were offered by the organization.

The survey was advertised in eight USENET newsgroups, requiring participants. These groups were selected on the basis of the contents of their ongoing discussions and were all expected to be interested in the telecommuting issue. Therefore, this is a convenience sample. To qualify as respondents, these individuals had to be employees whose jobs could be

performed at least part-time at home. It was not required that the option of telecommuting be offered.

About 100 individuals indicated their interest in participating in this survey. Fifty-four individuals actually answered the questionnaire, 46 of whom were males. Clearly, this sample is not representative of the potential telecommuting population, and no forecast can be made on the basis of these data. However, this does not prohibit the development of a model from which the weights of various factors can be studied for a specific segment of the population.

General Characteristics of the Sample

The average individual in the sample was 34 years old, a college graduate, married with no children, and part of a dual-career household. The average annual household income was $69,000. On average, two automobiles were available in each household. Ninety-four percent of the respondents had a personal computer or workstation at home, 85.5 percent had a modem, 42 percent had more than one telephone line, 23 percent had a fax machine, and 6 percent had a cellular phone. The majority of the individuals in the sample drove to work, and the average commuting time was 28 min.

On average, individuals had worked at their current job for 3.4 years for about 44 hr/week, and 71 percent of their working hours were spent at a computer. The computer was used primarily for programming, followed by communications. The most frequently used communication medium was electronic mail, followed by face-to-face contact, followed by telephone.

Individuals believed that given their job characteristics, it would be feasible to telecommute an average of 3.6 days/week, and they would like to telecommute about 3.3 days/week. From the total sample, 20 percent were given the option to telecommute on special occasions, and 45 percent were given the option to telecommute regularly. Sixty-two percent of the group that was given the option to telecommute regularly was allowed to telecommute on an informal basis.

Overview of Individuals' Perceptions

Table 1 shows the statements about telecommuting that individuals were requested to rate on a scale from 1 (entirely disagree) to 10 (entirely agree). Although these ratings are ordinal and should be interpreted carefully, they can provide some information on individuals' perceptions. According to the results, the main benefits of telecommuting are associated with increased flexibility, increased productivity, and reduced commuting stress. Overall, individuals in the sample perceived telecommuting to be a convenient arrangement, which is demonstrated in both the specific and the overall mean ratings.

Table 2 presents the statements made about the main barriers to a broader adoption of telecommuting by the organization for which the respondents work, which were rated on a scale from 1 (entirely disagree) to 10 (entirely agree). The two most relevant barriers seem to be the cultural requirement of 9:00 a.m. to 5:00 p.m. office hours and the lower efficiency of communication media when compared to face-to-face communication.

Even though this is a rather limited list of possible barriers to telecommuting, the responses seem to reinforce the belief that the biggest barrier is managerial reluctance. The lower efficiency of machine-mediated vis-a-vis face-to-face communications is also posed as a limiting factor, but it seems to be associated more with the frequency of telecommuting than with the decision of whether to adopt the arrangement.

Telecommuting Scenarios

To estimate the effects of different scenarios on individuals' willingness to telecommute, a conjoint experiment was designed, combining the attributes and levels presented in Table 3.

A fractional factorial design using two blocks of eight scenarios each was constructed. Each scenario involved a distinct combination of the five attributes described above. Each respondent was presented with one of the blocks and requested to make eight binary choices between one of the telecommuting options and the proposed nontelecommuting situation in which he or she would work 5 days per week in the office and overtime would be paid. The choices were made on an ordinal scale from 1 (would definitely not telecommute) to 5 (would definitely telecommute).

Estimation Method

A model was developed with the objective of evaluating the impacts of different working arrangements on individuals' decision of whether to telecommute. The underlying assumption

TABLE 1 Individuals' Perceptions About Telecommuting

Statement[2]	Statistics[1] Mean	Standard Deviation
increases autonomy	7.23	2.97
improves family life	6.53	2.70
increases flexibility	8.27	2.18
reduces commuting stress	7.46	3.02
increases productivity	7.65	1.96
negatively affects promotion	5.69	2.96
increases family/work conflict	3.90	2.81
saves a lot of money	5.50	3.10
makes worker feel isolated	5.19	2.76
overall, very convenient	8.56	1.94

[1] Total of 54 respondents

[2] Respondents were asked to grade each one of these statements about telecommuting on a scale from 1 = entirely disagree to 10 = entirely agree

TABLE 2 Barriers to Telecommuting

Statement[2]	Statistics[1] Mean	Standard Deviation
cultural requirement of 9-5 office hours	6.42	3.40
media not as efficient as face-to-face	6.19	2.33
not enough people on e-mail	3.29	3.01
not enough data on line	3.77	2.83
high cost of acquiring technology	3.87	2.74
high cost of using technology	3.46	2.42
technology doesn't match jobs needs	4.02	2.76

[1] Total of 54 respondents

[2] Respondents were asked to grade each one of these statements about telecommuting on a scale from 1 = entirely disagree to 10 = entirely agree

TABLE 3 Components of Conjoint Experiment

Attributes	Levels
Flexibility	Fixed schedule, 3 days at home, 2 days in the office
	Fixed schedule, 2 days at home, 3 days in the office
	Flexible schedule, at least 2 days in the office
	Flexible schedule, at least 1 day in the office
Technology Provider	Employee provides a computer and a modem
	Employer provides a computer and a modem
Telecommuting Costs	Employee pays phone bills
	Employer pays phone bills
Salary	10% less than office workers
	Same as office workers
	10% more than office workers
Overtime	Not paid
	Paid

was that individuals are utility maximizers and derive utility from combinations of attributes of the available alternatives. Due to imperfect information, utility is random, and can be written as

$$U_n^* = X_n\beta + u_n \tag{1}$$

where

U_n^* = utility derived from the alternative by individual n,
X_n = array of attributes of the available alternative to individual n,
u_n = random disturbance for individual n, and
β = array of parameters to be estimated.

Utility, however, cannot be measured. Instead, individuals' choices or stated preferences are observed and assumed to be indicators of their underlying utility function.

McKelvey and Zavoina (*17*) proposed a model to estimate the parameters of interest, β, when the observed indicators of the latent utility are ordinal, as in the case of the available data.

The ordinal probit model, as it is called, assumes that the random term of the underlying utility function is normally distributed.

$$u_n \sim N(0, \sigma) \tag{2}$$

It then associates the observed indicators with the underlying utility as follows:

$$Y_n \in R_m \Leftrightarrow \mu_{m-1} \leq U_n^* \leq \mu_m \tag{3}$$

where

Y_n = individual's response in observation n,
R_m = response category m,
μ_{m-1} = lower bound threshold for utility for response category m, and
μ_m = upper bound threshold for utility for response category m.

Because Y is ordinal, it can be represented as the following set of dummy variables:

$$Y_{nm} = \begin{cases} 1 & \text{if } Y_m \in R_m \\ 0 & \text{otherwise} \end{cases} \tag{4}$$

From Equations 1, 2, and 3, the probability function of the observed dependent variable, Y_{nm}, can be written as follows:

$$\begin{aligned} Y_{nm} = 1 &\Leftrightarrow \mu_{m-1} \leq U_n^* \leq \mu_m \Leftrightarrow \mu_{m-1} \\ &\leq \sum_{k=1}^{K} \beta_k X_{kn} + u_n \leq \mu_m \Leftrightarrow \left(\mu_{m-1} - \sum_{k=1}^{K} \beta_k X_{kn}\right)/\sigma \\ &\leq u_n/\sigma \leq \left(\mu_m - \sum_{k=1}^{K} \beta_k X_{kn}\right)/\sigma \end{aligned} \tag{5}$$

where $k = 1, \ldots, K$ represents the K attributes of the alternative. Because u_n is assumed to be normally distributed, it can be written

$$\begin{aligned} Pr(Y_{nm} = 1) = Pr(Y_n \in R_m) &= \Phi\left[\left(\mu_m - \sum_{k=1}^{K} \beta_k X_{kn}\right)/\sigma\right] \\ &- \Phi\left[\left(\mu_{m-1} - \sum_{k=1}^{K} \beta_k X_{kn}\right)/\sigma\right] \end{aligned} \tag{6}$$

where $\Phi(t)$ represents the cumulative standard normal distribution function. Assuming, without loss of generality, that $\sigma = 1$, the final model is given by

$$\begin{aligned} Pr(Y_{nm} = 1) = \Phi&\left(\mu_m - \sum_{k=1}^{K} \beta_k X_{kn}\right) \\ &- \Phi\left(\mu_{m-1} - \sum_{k=1}^{K} \beta_k X_{kn}\right) \end{aligned} \tag{7}$$

In addition, μ_0 is set to $-\infty$, μ_5 to $+\infty$, and μ_1 is arbitrarily set to zero, to fix the origin of the utility scale.

Initial Results

Table 4 shows the results of the ordered probit estimation based on the data collected. It should be noted that the ordered probit model assumes independence among observations, which, due to the data collection method, does not hold for this sample. As a result, the estimated coefficients are consistent, but not efficient. The resulting t-statistics are, therefore, overestimated. The Jackknife method [Miller (*18*)]

TABLE 4 Results from Ordered Probit Estimation

Variables Description	Statistics Mean	Standard Deviation	t-Statistics
dummy, if equipment provided by employee	-0.401	0.122	-3.020
dummy, if phone bills paid by employee	-0.442	0.123	-3.868
dummy, if overtime work is not paid	-0.229	0.100	-2.257
dummy, if salary reduction is proposed	-1.358	0.155	-8.244
dummy, if salary increase is proposed	0.504	0.151	3.834
number of children under 18 in the household	0.309	0.073	2.894
one-way travel time saved, if $\leq$ 40 minutes	0.012	0.008	0.947
one-way travel time saved, if > 40 minutes	-0.002	0.003	-0.211
number of years worked in the organization	-0.094	0.018	-0.485
dummy, if telecommuting option is not available	0.608	0.134	2.692
dummy, if respondent is female	0.521	0.207	1.164
threshold1	0.434	0.048	5.246
threshold2	0.875	0.050	7.773
threshold3	1.474	0.070	10.554
constant	2.002	0.215	7.793
Number of observations	432		
$\mathcal{L}(0)$	-594.710		
$\mathcal{L}(\beta)$	-448.690		
$\bar{\rho}^2$	0.271		

was applied to correct this problem, and the *t*-statistic values presented in Table 4 are the revised ones.

According to the model, all telecommuting costs (equipment provision, phone bills, and nonpaid overtime) have a negative impact on the decision to telecommute if they are to be borne by the telecommuters.

It is interesting to note that individuals react negatively to the hypothesis of having to provide a computer and a modem to telecommute, even though 94 percent of those people in the sample already have a personal computer or workstation at home. This result may indicate that the type of equipment individuals own is not compatible with that required to perform their work. More likely, however, it indicates that individuals ignore their current situation when responding to conjoint experiments.

The model coefficients also indicate that individuals react more negatively to a decrease in salary in exchange for telecommuting than they react positively to an incentive to telecommute in the form of a salary increase in the same proportion. The emphatic reaction to salary reduction was expected for several reasons. First of all, a 10 percent reduction in income may seem significant, unless the respondent is not the household "bread winner" and foresees possibilities of compensating for that loss through cost savings associated with home-based telecommuting. Moreover, this extreme reaction may be a manifestation of "policy bias" in which respondents want to make clear their position against some proposition, even though if they really need to face the situation they may be more flexible. Actually, according to the estimated parameters, the potential telecommuter would be willing to negotiate some salary reduction if the organization proposed to provide the required equipment and pay work-related phone bills and overtime hours.

Even though the individuals in this sample were willing to telecommute with no financial incentive, the parameter corresponding to an increase in salary is still significant. However, in a more diversified sample, where many individuals were not willing to telecommute in principle, the impact of this offer would probably be much lower.

The willingness to telecommute increases as the number of children in the household increases. The impact of this variable on the utility function, however, is more likely to be better represented by a stepwise function, increasing at a decreasing rate or even decreasing after a certain level. The low variability of the data in the sample, however, did not allow for testing of this hypothesis.

Neither variables representing commuting time savings have a significant impact on the model, and the parameter associated with savings in commuting time greater than 40 minutes has a counterintuitive sign. The most reasonable explanation for these results lies in the low commuting times observed in the sample, which may not represent a great inconvenience for commuters. Nevertheless, individuals do perceive reduction in commuting stress to be one of the main advantages of telecommuting, as previously indicated.

It was hypothesized that the more experience individuals have in their job, expressed by the number of years dedicated to it, the less attractive the telecommuting option would be, due to an increase in managerial responsibilities, and consequently, in the involvement with the job environment. Even though the corresponding variable has the expected sign, it is not significant, and this hypothesis can be rejected.

If individuals are currently not offered the choice to telecommute, they express more utility derived from telecommuting than those individuals who are actually given the option. This probably identifies a policy bias, common to stated preference data, in which individuals may overstate their preferences to favor their preferred policy.

Finally, a dummy variable was included to test whether men and women represent two distinct markets, as suggested in the literature. The *t*-statistic indicates that this variable is not significant. As a matter of fact, relevant market segments are expected to be defined by job category.

CONCLUSIONS

From the results presented in Table 1, the surveyed group appears to represent a specific market segment that favors

telecommuting, mainly for its nonmonetary potential benefits. Also, according to Table 2, the main constraint this group faces to adopt telecommuting is merely cultural. At first glance, these observations appear to indicate that these individuals would definitely adopt telecommuting if the option were available.

Nevertheless, the results in Table 4 show that the willingness to telecommute is not merely a function of individuals' characteristics and general attitudes toward telecommuting, but also of the characteristics of the working arrangement proposed.

This pilot study demonstrated that even though socioeconomic and attitudinal characteristics may be important in individuals' decisions to adopt telecommuting, they do not determine adoption because some trade-offs are made in considering the attributes of the proposed arrangement. The relevance of this finding lies in the fact that the organization has the possibility of making a telecommuting program more or less attractive to its employees, according to its own interests.

Due to difficulties in collecting data, the model was restricted to stated preferences, presenting validity problems. Therefore, even though it is useful to demonstrate the existence of trade-offs in the decision, the model would probably lead to imprecise forecasts. To improve the external validity of this model, some revealed preference data should be obtained to allow for a jointly estimated model [Morikawa (*19*)].

Moreover, the surveyed sample represents a specific stratum and does not represent the population as a whole. To obtain a broader picture of the attractiveness of telecommuting, a more diversified sample needs to be collected.

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