WHICH CAME FIRST, THE TELECOMMUTING OR THE RESIDENTIAL RELOCATION? AN EMPIRICAL ANALYSIS OF CAUSALITY[1]

David T. Ory and *Patricia L. Mokhtarian*[2]
Department of Civil and Environmental Engineering
and Institute of Transportation Studies
University of California, Davis

Abstract: Researchers have questioned whether the ability to telecommute is encouraging workers to relocate to more desirable residences farther from work, and in doing so, exacerbate sprawl and increase their net vehicle-miles traveled. The research presented here directly asks, is telecommuting a "friend or foe" of travel-reducing policies? Given that telecommuters tend to have longer commutes than non-telecommuters, is the ability to telecommute prompting workers to move farther away from work? Or rather, does the ability to telecommute allow those who for other reasons have already chosen, or would in any case choose, to live in more distant locations to commute less frequently? These questions are addressed using data collected from more than 200 State of California workers, including current, former, and non-telecommuters. The survey inquired retrospectively about their residential relocations, as well as their telecommuting engagements, over a 10-year period. The results indicate that, as expected, residential moves that are temporally associated with telecommuting episodes tend to increase commute time and length compared to other moves—although the differences are not statistically significant. Analyzing the temporal order of telecommuting engagement and residential relocation, the data show that those who are telecommuting and then move actually tend to relocate *closer* to their workplace, whereas those who begin telecommuting following a residential relocation tended to have moved much farther from their workplace. Analysis of the stated importance of telecommuting to specific residential relocations did not show a convincing effect toward more distant moves. Thus, the evidence more strongly supports the positive view of telecommuting, that it is ameliorating the negative transportation impacts of moves that occur for other reasons. [Key words: commuting, residential location, retrospective survey, telecommuting, teleworking, work at home.]

INTRODUCTION

Telecommuting, defined here as working from home or a nearby center instead of going to the normal workplace at the usual time (excluding overtime work at home,

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[2]Correspondence concerning this article should be addressed to Patricia L. Mokhtarian, Department of Civil and Environmental Engineering, University of California, Davis, Davis, CA 95616; telephone: 530-752-7062; fax: 530-752-7872; e-mail: plmokhtarian@ucdavis.edu

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home-based businesses, work while traveling, or required work at a field location), has found a niche in U.S. transportation policy. In response to a number of convincing empirical studies (e.g., Hamer et al., 1991; Mokhtarian et al., 1995; Mokhtarian, 1998) that have found net reductions in the vehicle-miles traveled by telecommuters (on days they telecommute), policy makers at the state and national level have begun to incorporate telecommuting alternatives into law. For example, United States Public Law 106-346 (Sec. 359, October 23, 2000, available at http://thomas.loc.gov/bss/d106/d106laws.html, accessed December 4, 2006) states, "each executive agency [of the Federal government] shall establish a policy under which eligible employees of the agency may participate in telecommuting to the maximum extent possible without diminished employee performance."

The problem with the empirical evidence to date is that it tracks travel behavior over a very short period of time after the adoption of telecommuting—typically one to two years. The long-term impacts of telecommuting on travel, specifically commute travel, are not fully known. Certainly the evidence so far indicates telecommuting may reduce overall travel, but some researchers (see, e.g., Janelle, 1986, for an early source of this idea; and Graham and Marvin, 1996, for a thorough discussion of both sides of the issue) have suggested that the ability to telecommute could, over time, prompt individuals to move farther away from their jobs to cheaper or higher-amenity residential locations. Such moves would require longer, though less frequent, commutes that may lead to a net increase in vehicle-miles traveled (VMT). To the extent such behavior occurs, telecommuting alternatives could accelerate urban sprawl, and may not serve their intended role of reducing travel. Suspicion of telecommuting deepens with the observation of several studies (e.g., Mokhtarian et al., 1995; Gareis, 2003; Shaw, 2004) that telecommuters tend to have significantly longer commutes than do non-telecommuters.

On the other hand, the latter observation is not conclusive because the causal relationship could be in the opposite direction: people who have already moved far from work would naturally be more motivated to adopt telecommuting after the fact, as a solution to, rather than a cause of, their longer commute.

Thus, we ask: is telecommuting a friend or foe of travel reduction policies? Is the ability to telecommute prompting workers to move farther away from work (and hence, perhaps, to increase their overall commute distance)? Or, does the ability to telecommute allow people, who for other reasons have already chosen (or would in any case choose) to live in more distant locations, to commute less frequently (and hence to reduce their total commute amount from what it would have been without telecommuting, even if it is still more than it was before the move)?

It is important to keep in mind that telecommuters would not move farther from work just *because* they are able to telecommute. Rather, in the "foe" scenario, telecommuting simply makes possible a move that is desired for other reasons—to accommodate household needs, to obtain a larger and/or cheaper home, to be near scenic locations or other amenities, and so on. Thus, in this scenario, telecommuting can be viewed as a facilitator, not an actual driver, of such moves. Nevertheless, to the extent telecommuting is responsible for releasing a constraint that was preventing further decentralization (and to the extent such decentralization is considered socially undesirable, a point subject to debate, e.g., by Ewing, 1997; Gordon and Richardson, 1997; Filion et al., 2004; Kirby, 2004), telecommuting is arguably as culpable as if it were a driver in its own right. In reality, of

course, it could be rather difficult to disentangle the relative roles of drivers and facilitators, to determine the extent to which one factor could be singled out as being responsible for the move, as opposed to a number of factors acting in concert, with indivisible impact.

Several studies have examined the long-term impacts of telecommuting on residential location and hence urban form, using, as a starting point, the land use theory of Alonso (1964). Higano and Orishimo (1990), Lund and Mokhtarian (1994), Kim (1997), and Safirova (2002) assumed a monocentric city; Stough and Paelinck (1996) and Shen (2000) relax the monocentric assumption in different ways. Each of these studies found, not surprisingly, that telecommuting can increase the decentralization of a city compared to that of a non-telecommuting baseline. However, none of these theoretical models has been empirically verified. Unfortunately, the ideal data set, which would track telecommuters and comparable non-telecommuters over a substantial period of time (e.g., 10 years), does not exist. As a result, it remains difficult to confirm or refute the alternative conjectures regarding the causal relationship between telecommuting and residential relocation.

In lieu of the ideal data set described above, the present study analyzes a single cross-sectional survey of current, former, and non-telecommuters—inquiring retrospectively about their residential and job relocations, as well as their telecommuting engagement patterns, over a 10-year period (from the autumn of 1988 to the fall of 1998). Though such data are obviously subject to recall error, the changing of residence or job location is probably an important enough life event to be recalled with the desired accuracy—the unit of analysis being a quarter-year or three-month period (for a more detailed discussion of the use of retrospective surveys for collecting residential relocation data, see Hollingworth and Miller, 1996; for an example of retrospective data collection on commute mode information spanning several decades, see Pooley and Turnbull, 2000). Telecommuting engagement is probably a less significant life event, though perhaps memorable enough that respondents seemed to have little trouble answering the questions in the survey (relatively few missing or unclear data). To our knowledge, this study (including other analyses of the same data) constitutes the first attempt to empirically examine relationships among telecommuting, residential location, and total commute travel over a 10-year period.

A previous analysis of these data (Mokhtarian et al., 2004) confirmed that in this sample, too, telecommuters lived farther from work than non-telecommuters. However, it also found that the telecommuters telecommuted often enough to more than compensate for this: the total per capita commute distance traveled by telecommuters was smaller than for non-telecommuters. A later extension of that analysis (Ory and Mokhtarian, in press) found that telecommuters also commuted for shorter durations than non-telecommuters, with the majority of that time savings due to faster travel speeds. Those studies, however, did not address whether the longer one-way commute length of telecommuters was a cause, or an effect, of their telecommuting. In contrast, the focus of the present analysis will be on attempting to ascertain causality.

To do so, we will use three distinct methods of analysis. First, we will compare the changes in one-way commute length following residential relocations for telecommuters and non-telecommuters, to answer the question: are telecommuters *moving* farther from work than non-telecommuters? If they are not (as was found in an earlier, short-term, study of State of California workers conducted by Nilles, 1991), the conceptual basis for inferring that telecommuting is stimulating further decentralization is undermined. If they

are, on the other hand, it still remains to ascertain whether the increased commute length is caused by telecommuting, or whether telecommuting results from the move. Thus, this approach does not address the causality question directly. It does, however, constitute a necessary benchmark against which to gauge the rest of the investigation.

In the second method of analysis, the timing of the moves in relation to the timing of telecommuting engagement is used to infer causality: temporal precedence of X over Y is generally viewed (where there is also conceptual and statistical justification) as strengthening the inference that X caused Y rather than the reverse (e.g., Baumrind, 1983; Holland, 1986). However, temporal precedence is not completely definitive, of course. For one thing, the timing might simply be coincidence, and neither event be related to the other. After all, people move closer to and farther from work all the time, for a variety of reasons that most often have nothing to do with telecommuting. Conversely, people telecommute for reasons having nothing to do with reducing travel, such as increasing their concentration (one-way commute distances as short as three miles have been reported by telecommuters in some studies).

Even if a relationship is present, it might not be the obvious one. If Y follows X, did X cause Y, or did the *anticipation of* Y cause X? Although the *implementation* of telecommuting may follow a residential move in time, the actual *choice* to telecommute may have preceded and prompted the move. Conversely, if a residential move followed the start of a telecommuting episode, it is possible that the *decision* to move preceded and prompted the telecommuting.

To help address these kinds of ambiguities, one may say, "Why not just ask whether the move took place because of telecommuting?" The survey instrument used in this study does, in fact, directly ask respondents to rate the importance that telecommuting played in their relocation decision, and investigating these responses is the third analysis approach we use. But these answers may not be reliable (though still worth examining) because respondents completing a survey regarding their telecommuting engagement may consciously or unconsciously report telecommuting as being more important than it really is, due to their heightened awareness of it.

These three methods—comparing the resulting commute characteristics following the relocation of telecommuters and non-telecommuters, assessing the timing of moves, and examining the stated causality for the moves—although each are limited in different ways, should together offer useful insights into the causal relationship between telecommuting and residential relocation. To the extent that multiple methods point to similar conclusions, our confidence in the result increases.

The next section of the paper discusses the data in greater detail. Three sections of analysis follow, namely: comparing the relocation patterns of telecommuters and non-telecommuters; addressing the issue of causality by investigating the timing of relocations in relation to the timing of telecommuting engagements; and examining the stated importance of telecommuting in the decision to make a residential move, as recorded in the survey instrument. A concluding section ends the paper.

EMPIRICAL SETTING AND AVAILABLE DATA

From 1988 to 1990, the State of California conducted one of the best-known early telecommuting pilot programs for its employees, involving around 150 telecommuters in

14 state government agencies (JALA Associates, 1990; Kitamura et al., 1990). Through the years, telecommuting has continued to thrive in some of these agencies, offering an opportunity to explore the long-term relationships of interest in this study.

To gather the desired data, a 16-page self-administered survey was designed and distributed in November 1998 to employees of the following six California state agencies: California Energy Commission, Department of Personnel Administration, Franchise Tax Board, California Youth Authority, Department of Motor Vehicles, and Department of Social Services. Each of these agencies has kept their telecommuting programs active since the pilot implementation in 1988.

The survey was distributed to those who responded to a broadcast recruitment email to key divisions or groups within each agency. The message stressed the need for participation from telecommuters, non-telecommuters, and former telecommuters, and offered a drawing for cash prizes of $250, $150, and $100. Due to the intended approach of enriching the sample with telecommuters, the data are not representative of any general population—that is, the ratio of telecommuters to non-telecommuters in the sample is higher than in the population as a whole. However, to the extent that each subsample is representative of the population from which it is drawn, comparisons of average behavior across subsamples will be valid even if the share of the sample in each group is not itself representative.

Thus, more important, and independent from the representativeness of the telecommuter/non-telecommuter ratio, is the question of whether the telecommuters in the sample are representative of the general population of telecommuters. Unfortunately, there are no reliable data on the demographics and other characteristics of telecommuters in the population, making any comparison of our sample (e.g., in terms of gender, income) to the population of telecommuters impossible. We speculate, however, that over the 10-year retrospective period covered by the survey, the sample of telecommuters may be less representative the farther back in time we go. That is, we suspect that from our sample, collected entirely in 1998, the subset identified as telecommuting in Fall 1988 could be less representative of telecommuters at that point in time than is the subset identified as telecommuting in Summer 1998. Specifically, we speculate that people who remember telecommuting 10 years ago well enough to report it on a survey a decade later may have had more extreme circumstances than the typical telecommuter of that time (see Mokhtarian et al., 2004, for further discussion on this issue, and on whether the non-telecommuters serve as an appropriate control group).

An additional potential for bias is the fact that sample is composed solely of state employees. The attitudes, opinions, and behaviors of government employees may differ in a systematic way from those of private sector employees. For instance, state workers may have more stable jobs and less wage uncertainty than their private-sector counterparts. Government agencies may also have a stronger and more public commitment to telecommuting than do many private sector employers, in view of public policy motivations to foster it (reductions in congestion, fuel consumption, and emissions; provision of employment opportunities to mobility-limited segments of society; promotion of family-friendly work policies; and, in recent times, continuity of operations following extreme events affecting workplaces and/or the transportation network). However, it has been our observation that: (1) regardless of the organization's putative position on telecommuting, the climate for actually doing it is only as favorable as a worker's direct supervisor wants it to

be; (2) many government agencies have not been notably supportive overall; and (3), conversely, many units within private sector corporations have enthusiastically embraced it, whether for "mission-oriented" reasons of their own, such as to promote the sales of telecommunications equipment and services, or from a more generic conviction that it is good for business (e.g., through improving customer service or employee morale, productivity, or retention). Thus, we do not perceive a substantive difference between the public and private sectors overall, in their adoption of telecommuting. Accordingly, we have no strong reason to expect a difference between these two groups with respect to the causal relationship between telecommuting and residential relocation.

Both public-sector and private-sector populations of telecommuting salaried employees, however, are likely to differ from the other populations of teleworkers mentioned in the Introduction. In particular, anecdotal evidence suggests a trend toward self-employed professionals choosing residential locations in amenity-rich areas (referred to as the "lone eagle" phenomenon in resort towns in the Rocky Mountains; e.g., Bonfonte, 1993; Braus, 1993; Hannon, 1995), at least in part facilitated by telecommunications technology. We are not aware of rigorous empirical research on the residential location behavior of a representative sample of this population of self-employed professionals (as opposed to interesting examples which may or may not be "typical"). In any case, however, it should be kept in mind that the empirical results reported in the present study (based, as they are, on salaried employees) are not purported to be transferable at all to such self-employed full-time teleworkers.

Other limitations of the sample include its age (communications technology has improved dramatically since the data were collected in the late 1990s) and its relatively small size (which makes analyzing the data by various sociodemographic market segments impossible). Nevertheless, the unique data on telecommuting frequency and residential relocation over time allows for perhaps the most sophisticated analysis to date of the causal relationship studied here. Important sociodemographic characteristics of the sample are included in Table 1.

The survey instrument contained two 10-year timelines (segmented into quarter-years) that captured the key data for this analysis. On the first timeline, current and former telecommuters indicated all the periods of time during which they telecommuted regularly, the frequency with which they telecommuted during each of those periods, and reasons for quitting or changing frequency in each case. ("Regular" telecommuting was defined as "at least two days a month on average, for at least three consecutive months.") On the second timeline, all respondents recorded their job and residential relocations that took place during the 10-year span and, for each job-residence location pair (including the pair at the beginning of the 10-year period), indicated their commute length, time, and mode. The two timelines were separated by three pages, so although respondents could have made a conscious effort to "match them up," they were not particularly led to do so by the survey design.

In addition to the timelines, the survey collected data on attitudes toward telecommuting; reasons for, and other characteristics of, their three most recent residential relocations; impacts of telecommuting on relocations and vice versa; impacts of telecommuting on frequency and destination for a number of trip purposes; general transportation-related choices; job characteristics, home characteristics, and standard sociodemographic characteristics. The current study focuses on the information available from the two timelines

TABLE 1. KEY CHARACTERISTICS OF THE SAMPLE[a]

	Total sample	Current Telecommuters	Former Telecommuters	Never Telecommuters
Categorical/ordinal variables: Frequency (column %)				
Gender				
Female	150 (68.8)	45 (72.6)	26 (74.3)	79 (65.3)
Male	68 (31.2)	17 (27.4)	9 (25.7)	42 (34.7)
Total	218 (100.0)	62 (100.0)	35 (100.0)	121 (100.0)
Occupation				
Manager/administrator	29 (13.3)	6 (9.7)	6 (17.1)	17 (14.0)
Professional/technical	161 (73.9)	53 (85.5)	24 (68.6)	84 (69.4)
Administrative support	23 (10.6)	2 (3.2)	5 (14.3)	16 (13.2)
Other	3 (1.4)	1 (1.6)	– (–)	2 (1.7)
Total	216 (99.1)	62 (100.0)	35 (100.0)	119 (98.3)
Education				
Some grade or high school	2 (0.9)	– (–)	1 (2.9)	1 (0.8)
High school graduate	3 (1.4)	– (–)	– (–)	3 (2.5)
Some college	86 (39.4)	20 (32.3)	14 (40.0)	51 (43.0)
Four-year college degree	62 (28.4)	22 (35.5)	6 (17.1)	34 (28.1)
Some graduate school	32 (14.7)	10 (16.1)	5 (14.3)	17 (14.0)
Completed graduate degree	31 (14.2)	10 (16.1)	8 (22.9)	13 (10.7)
Total	216 (99.1)	62 (100.0)	34 (97.1)	120 (99.2)
Annual personal income				
Less than $15,000	3 (1.4)	1 (1.6)	– (–)	2 (1.7)
$15,000 to 34,999	40 (18.3)	5 (8.1)	4 (11.4)	31 (25.6)
$35,000 to 54,999	93 (42.7)	27 (43.5)	21 (60.0)	45 (37.2)
$55,000 to 74,999	49 (22.5)	18 (29.0)	3 (8.6)	28 (23.1)
$75,000 to 94,999	18 (8.3)	5 (8.1)	4 (11.4)	9 (7.4)
$95,000 or more	15 (6.9)	6 (9.7)	3 (8.6)	6 (5.0)
Total	218 (100.0)	62 (100.0)	35 (100.0)	121 (100.0)
Residential area type				
Large city	91 (41.7)	21 (33.9)	15 (42.9)	55 (45.5)
Suburb of large city	59 (27.1)	18 (29.0)	11 (31.4)	30 (24.8)
Medium-size city	25 (11.5)	10 (16.1)	5 (14.3)	10 (8.3)
Small city	17 (7.8)	2 (3.2)	3 (8.6)	12 (9.9)
Town or village	6 (2.8)	1 (1.6)	– (–)	5 (4.1)
Countryside	18 (8.3)	9 (14.5)	1 (2.9)	8 (6.6)
Total	216 (99.1)	61 (98.4)	35 (100.0)	120 (99.2)
Continuous variables: Mean (s.d., *N*)				
Age	43.2 (8.7, 217)	43.2 (8.6, 62)	44.7 (8.9, 35)	42.8 (8.8, 120)
Household size	2.8 (1.4, 218)	2.7 (1.3, 62)	3.0 (1.1, 35)	2.9 (1.4, 121)

[a]All characteristics (including classification as Current, Former, and Never Telecommuters) were measured at the time of data collection in 1998, the final quarter of the 10-year (retrospective) study period.
Source: Mokhtarian et al. (2004).

as well as the questions about the role of telecommuting in relocations; preliminary analysis of other parts of the survey can be found in Gertz and Mokhtarian (1999).

This study analyzes the 218 individuals having essentially complete timeline responses. Over the 10-year period, these 218 individuals changed residential locations only (i.e., no accompanying job change) 198 times, and changed both job and residential locations in the same quarter 76 times. The focus of the analysis presented here will be on the changing commute characteristics of each move, comparing those characteristics between telecommuters and non-telecommuters, and the timing of those moves in relation to telecommuting engagement. Of course, as indicated earlier, the relocations examined could be taking place for any number of reasons, and may not even be the decision of the individual reporting the change (e.g., the spouse may be driving the residential move). However, to the extent these varying circumstances are present in both the telecommuter and non-telecommuter samples, the differences between the two groups can be suggestively attributed to telecommuting.

RELOCATION PATTERNS OF TELECOMMUTERS AND NON-TELECOMMUTERS

In this first stage of analysis, the residential relocation patterns (and, more importantly, the commute characteristics) of telecommuters and non-telecommuters are compared. The goal is to determine if telecommuters, on average, select homes that are farther away from their workplaces than non-telecommuters do.

When assessing the impact of telecommuting in the analysis, the rules for labeling each individual, or more specifically labeling each individual in each quarter-year time period, as a telecommuter or a non-telecommuter are important. The survey instrument defined telecommuting simply as "…working from home (or a nearby center) instead of going to your normal workplace at the usual time." The respondents were instructed to indicate on the timeline the quarters in which they telecommuted "regularly"—defined as "at least two days a month on average, for at least three consecutive months."

Each individual in the sample is defined as a telecommuter (or not) in four different ways in each quarter-year, as follows: (1) *current telecommuter*—individual telecommuting regularly during the current time period; (2) *non-telecommuter*—individual NOT telecommuting regularly during the current time period; (3) *ever telecommuter*—individual who telecommutes regularly at any point during the 10-year data collection period (varies by individual level but not by quarter); (4) *never telecommuter*—individual who does NOT telecommute regularly at any point during the 10-year data collection period (also varies by individual but not quarter). Thus, at any given quarter the sample can be partitioned into Current and Non-telecommuters or, independent of quarter, into Ever and Never Telecommuters. Due to the bounded time frame in which the data were collected, the Ever/Never definitions will erroneously classify individuals when their past or future telecommuting engagement falls outside the 10-year period of the survey instrument. Also, the arbitrary nature of the definition of "regular" telecommuting will impact the classification. However, any duration and frequency requirements will be arbitrary, and given the fact that one's telecommuting status is always a "moving target," these definitions should reasonably well capture the behavior of the groups of interest over a typical 10-year period.

TABLE 2. SUMMARY OF RESIDENTIAL RELOCATIONS BY TELECOMMUTERS AND NON-TELECOMMUTERS

Status	Average change in commute length		Average change in commute duration	
	Number of moves[a]	Miles (% change)	Number of moves[a]	Minutes (% change)
Everyone	183	2.02 (13.3%)	181	2.40 (8.1%)
Current Telecommuter[b]	19	2.95 (16.3%)	19	6.74 (22.6%)
Non-telecommuter[b]	164	1.91 (12.9%)	162	1.89 (6.4%)

[a]The numbers shown are the number of moves (not respondents) with valid data.
[b]Designation refers to the respondent's status during the quarter of the move.

Table 2 cross-tabulates the resulting commute characteristics of Current Telecommuters and Non-telecommuters following residential moves made by respondents in the sample.[3] The table shows an overall average increase in one-way commute length and duration of about 2.02 miles (a 13.3% increase from the pre-move average commute length of 15.19 miles) and 2.40 minutes (8.1%), respectively. This result is expected and indicates that the sample as a whole is increasing its commute length and duration following a residential move. Since the sample contains a minority of telecommuters, this result is a useful reminder that decentralization is by no means confined to telecommuters. The fact that the average changes in commute time and length are positive for the sample overall, and for the non-telecommuters as well as telecommuters, reinforces the observation that ongoing decentralization is occurring independent of telecommuting, and complicates the effort to separate any effects of telecommuting specifically, from this general trend affecting everyone.

When segmenting the sample based on telecommuting status, however, it becomes evident that telecommuters, on average, tend to move farther away from their workplaces than non-telecommuters. In Table 2, telecommuters are distinguished based on their telecommuting status the quarter of the move—if respondents were telecommuting during the quarter in which they changed residences, they are considered telecommuters (other definitions of "telecommuter" were analyzed in Ory and Mokhtarian, 2005, with no important differences in the results). These telecommuters increase their commute length and duration more than non-telecommuters do when making a residential relocation. While the results do show a general trend of telecommuters relocating farther from their jobs than non-telecommuters, it should be noted that the differences between these groups are not statistically significant at the 95% confidence level—a result of the small sample size and relatively large variances in length and duration changes.

[3]Those making "simultaneous" job and residential relocations—i.e., within the same quarter—are not considered in this analysis on the assumption—supported by Clark et al. (2003)—that such moves could differ importantly from residential-only moves, but without enough of them—only 2 of the 76 simultaneous moves were made by telecommuters—to analyze separately.

TABLE 3. DIFFERENCES IN RESIDENTIAL MOVE COMMUTE LENGTHS AMONG CURRENT, FORMER/FUTURE, AND NEVER TELECOMMUTERS

	Ever Telecommuter					
	Current Telecommuter		Non-telecommuter		Never Telecommuter	
Direction of move in relation to job location	N[a] (%)	Change in commute length[b]	N (%)	Change in commute length	N (%)	Change in commute length
Closer	9 (47.4)	–13.1	18 (34.0)	–14.3	36 (32.7)	–9.2
Zero	2 (10.5)	0.0	7 (13.2)	0.0	27 (24.5)	0.0
Farther	8 (42.1)	21.8	28 (52.8)	16.3	47 (42.7)	9.4
All	19 (100.0)	2.95	53 (100.0)	3.72	110 (100.0)	1.02

[a]Number of valid commute length measures in each group.
[b]Average change in one-way commute length, in miles, following a residential relocation.

A more detailed cross tabulation of changes in commute distance following a residential move is presented in Table 3. Here, the sample is first segmented into Ever Telecommuters (those who at some point in the 10-year study period engaged in regular telecommuting) and Never Telecommuters (those who did not engage). Ever Telecommuters are then segmented further by the Current Telecommuter definition (as in Table 2) to distinguish between telecommuting and non-telecommuting quarters. This segmentation allows for a comparison among three groups: those who are currently telecommuting in a quarter of residential relocation, those who are not currently telecommuting but have telecommuted in the past or will telecommute in the future (within the study period), and those who at no point in the study period telecommuted. We further segment moves by whether they are closer to work, farther from work, or the same distance away.

Table 3 indicates that those who are currently telecommuting behave differently from those who never telecommute, but not that differently from those who telecommute at some point, yet are not doing so at the current time. The difference in change in commute length for those who are currently telecommuting and those who are not, but have in the past or will in the future, is rather small. In contrast, those who never telecommute have a much smaller average change in commute length than both of the other groups.

Table 3 shows that, ironically, for the two groups *not* telecommuting in the relocation quarter, moves were more often farther from work than closer to it, whereas Current Telecommuters moved closer to work about as often as they moved farther away. This picture shifts, however, when changes in the commute length itself are considered. For the Never Telecommuters, moves farther from work increased the commute by slightly more than moves closer to work reduced it, and there are enough more of the former that the net average change in commute length was one mile farther away. Similar but stronger patterns for the Non-telecommuters result in a net average increase of 3.72 miles. For Current Telecommuters, on the other hand, moves farther from work increased the commute substantially more than moves closer to work reduced it, but since the numbers

TABLE 4. CAUSAL INFERENCES BASED ON TIMING OF MOVES AND TELECOMMUTING ENGAGEMENT

Before relocation	After relocation: Not telecommuting	After relocation: Telecommuting
Not telecommuting	No relationship (control)	Relocation caused telecommuting (beneficial)
Telecommuting	No influence of telecommuting (telecommute quitters)	Telecommuting caused relocation (detrimental)

of moves in each category are nearly balanced, the net increase is three miles, smaller than for the Non-telecommuters.

In sum, Current Telecommuters move farther from work relatively less often than do Non- and Never Telecommuters, but when they do move farther away, it tends to be substantially farther away than the other two groups. The net change in commute length for Current Telecommuters falls between that of Non-telecommuters and Never Telecommuters. Again, however, the *t*-statistics comparing the overall means of these three groups show no statistical difference between any pair of groups at the 95% confidence level. Similarly, chi-squared tests show no statistical difference in the distributions among these groups at the 95% level (the moves were segmented within groups based on the distance of the moves, information not shown in Table 3), although the Current Telecommuter group is distributed differently from the Never Telecommuter group at the 90% level. Overall, then, indications are that telecommuters are moving farther away from their workplaces than non-telecommuters are, but the statistical evidence is relatively weak.

TIMING OF RELOCATIONS AND TELECOMMUTING ENGAGEMENT

The aim of the previous section was to determine whether telecommuters, on average, choose to live and work farther apart than non-telecommuters, and it appears they do, although statistically the differences are not substantial. This section gets to the heart of the paper: is the ability to telecommute causing this increase in length and duration (the "foe" scenario), or is telecommuting allowing less frequent commuting to take place for moves that would have happened anyway (the "friend" scenario)?

The timing of the residential moves in relation to the timing of telecommuting engagement is examined in an attempt to answer these questions. The causal inferences based on the timing of the relocation and telecommuting are summarized in Table 4. The rows in Table 4 represent the status of telecommuting engagement the quarter immediately preceding the relocation; the columns represent the telecommuting engagement status the quarter immediately following the relocation (we later informally examine periods of time around the move longer than one quarter). For example, if an individual is regularly telecommuting the quarter preceding a move (i.e., a Current Telecommuter) she is considered to be "telecommuting" before the relocation. If she is also telecommuting regularly the quarter after the relocation, she is considered to be telecommuting after the

TABLE 5. CHANGES IN COMMUTE CHARACTERISTICS OF RESIDENTIAL MOVERS SEGMENTED BY TELECOMMUTING CAUSALITY CATEGORIES[a]

Before relocation	After relocation: Not telecommuting (No)	After relocation: Telecommuting (Yes)
Not telecommuting (No)	Control 148[b] 1.23 minutes (4.3%) 1.17 miles (8.4%)	Relocation causes telecommuting 13 17.69 minutes (56.8%) 14.54 miles (84.4%)
Telecommuting (Yes)	Telecommute quitters Only one observation in this category (data suppressed)	Telecommuting causes relocation 15 –3.00 minutes (8.7%) –3.73 miles (17.5%)

[a]The first row in each cell denotes the label given to the group. The second row contains the number of observations (moves). The third row contains the average change in one-way commute duration following a residential move, with the percent change from the before-move average duration in parentheses. The fourth row contains the average change in one-way commute length following a residential move, again with the percent change in parentheses.
[b]148 valid observations for the commute duration variable and 150 valid observations for the commute length variable.

relocation, and would be placed in the lower-right hand cell of the matrix. The telecommuting status the same quarter of the relocation is not considered, since it cannot be used to establish temporal precedence and since one's status during the periods before and after the move is arguably more relevant to the question of causality.

Each cell of the matrix allows for a different inference to be made about the causal relationship between telecommuting and relocation. Individuals who telecommute neither before nor after a relocation (the upper-left cell) presumably moved independently of telecommuting, and are referred to as the control group. Similarly, if a person telecommuted before, but not after a move (the lower-left cell), it is concluded that telecommuting did not influence the move (although the move may well have influenced the cessation of telecommuting); these cases are referred to as "telecommute quitters."

The key groups of interest are those in the right-hand side of the table. Individuals who do not telecommute before a move, but do telecommute after a move (the upper-right cell) are assumed (for the sake of discussion—as mentioned in the Introduction, this evidence is not definitive) to have their telecommuting engagement caused by the relocation. Conversely, those in the lower-right cell are assumed to have their relocation prompted by the ability to telecommute because they begin telecommuting, then relocate, and continue to telecommute.

After segmenting the sample into these four causal blocks, the number of moves and net changes in commute characteristics of each block, following relocation, can be examined. This summary for residential relocations is presented in Table 5. Each of the four blocks in the table contains the number of moves in each group, the resulting average

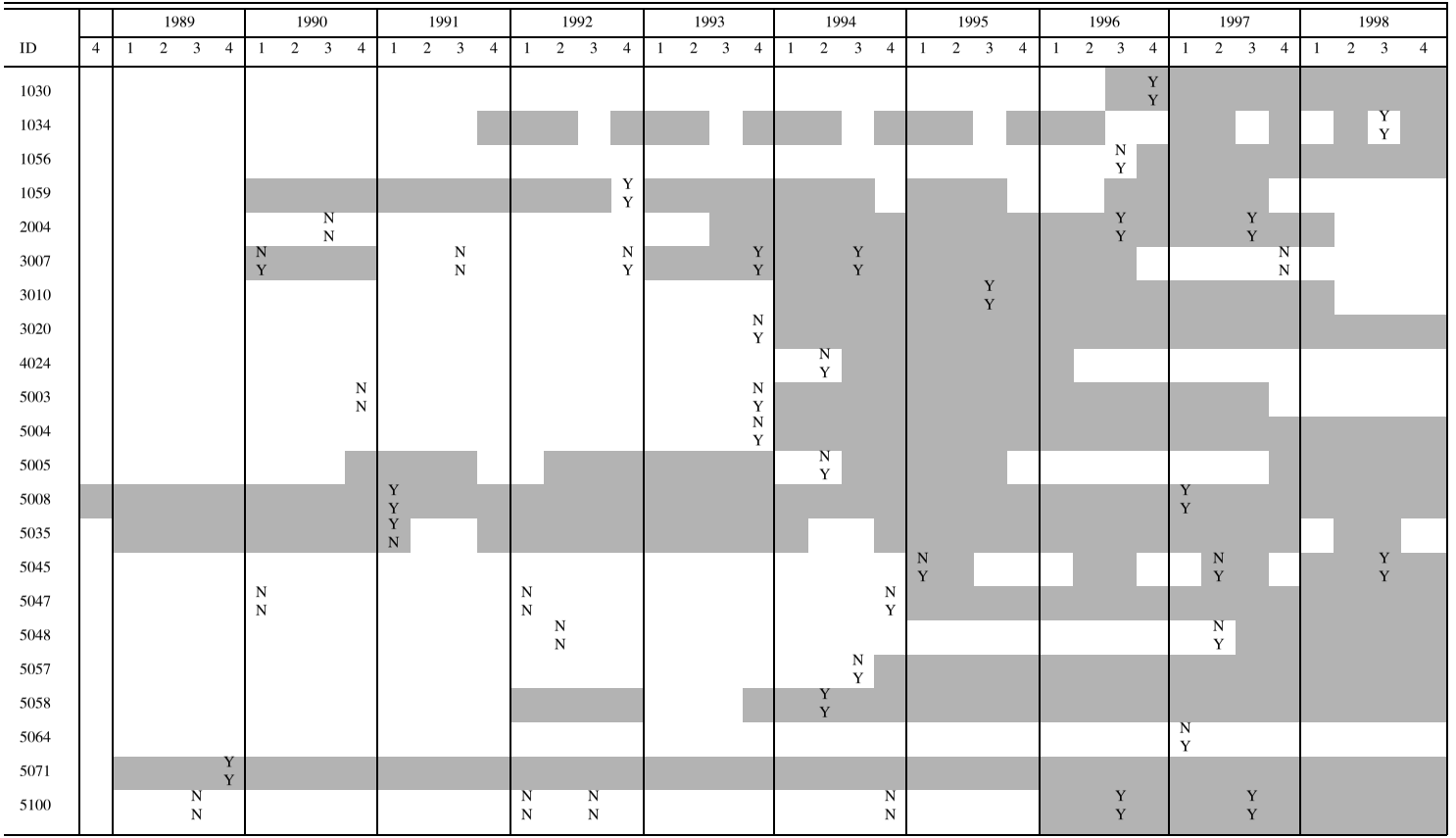
change in one-way commute duration (in minutes), and the resulting average change in one-way commute length (in miles). Although the two key groups (NY and YY, where N = no and Y = yes) have small sample sizes (13 and 15 moves, respectively), their average before-move commute characteristics are not very different (NY: 31-minute average commute time; 17-mile average commute distance; YY: 34 minutes and 21 miles), whereas the changes due to the moves could hardly be more disparate. Those who are inferred to have their telecommuting engagement caused by their residential relocation (the NY group) tend to move away from their workplace—increasing their commute time by about 18 minutes and their commute length by 15 miles. In this scenario, an individual moves to a more distant residential location and, presumably in response to the increased commute, begins telecommuting. Here, the telecommuting is a "friend" of travel-reducing policies, as the longer commute is relieved, to some degree, by telecommuting.

On the other side of the causal argument, those who are assumed to have their relocation caused by telecommuting (the YY group) actually tend to move *closer* to their workplace—an average reduction in commute time of 3 minutes and commute length of nearly 4 miles. Thus, in this possible "foe" scenario, the negative changes in commute duration make telecommuting at worst neutral to, and at best a friend of travel-reducing policies. Though the small sample size may mean this result is simply due to random variation, it is consistent with the Telework America 2001 finding (Davis and Polonko, 2001) that teleworkers (who, it should be noted, are defined differently than the telecommuters studied here) moved closer to their jobs 52% of the time, and farther from their jobs 29% of the time. It may be that some individuals who were telecommuting to reduce their commute travel were not satisfied enough with the result, and moved closer to work to further improve their commute profile. A related explanation (observed anecdotally by the second author) is that telecommuting (even if adopted for reasons unrelated to travel) heightened individuals' awareness of the burdensome commute, and generated or strengthened the resolve to find an even more effective solution to it. Ellen and Hempstead (2002) proposed that young, tech-savvy telecommuters may be drawn, once their incomes allow, to more urban, central locations; these results loosely support their findings. Last, the result may be at least in part due to a "regression to the mean" effect (Campbell and Stanley, 1963). This pattern, in which those with longer commutes (here, more often telecommuters) tend to shorten them when moving, while those with shorter commutes tend to lengthen them, was observed (though not labeled as such) by Clark et al. (2003) in a study not specific to telecommuting. However, such an effect is blurred by the overall increases in mean commute distance observed earlier (i.e., a tendency toward shortening a long or lengthening a short commute is superimposed on a background tendency toward lengthening).

Table 6 presents a graphical representation of the residential relocation and telecommuting patterns of the sample, on which the results in Table 5 are based. The residential relocations are denoted by a two-letter symbol (NN, YN, NY, YY), which corresponds to the four causal groups discussed previously. Quarters in which the respondent telecommuted are shaded grey and quarters in which they did not are left white. Only respondents with a move relating to the two key causal groups are presented in the table.

In addition to offering an easy visual representation of telecommuting engagement and residential relocation through time, Table 6 also helps to validate the methodology used to segment the sample into causal groups. Recall, the causal segmentation was based

TABLE 6. TEMPORAL INCIDENCE OF TELECOMMUTING EPISODES AND RESIDENTIAL RELOCATION[a]



[a]YY = telecommuting engagement one quarter before and after move; YN = telecommuting engagement before, but not after move; NY = telecommuting engagement after, but not before move; NN = not telecommuting before or after move; shaded region indicates telecommuting engagement during the quarter; blank region indicates no telecommuting engagement.

solely on the telecommuting engagement status the quarter immediately preceding and immediately following the residential relocation. If, for example, an individual telecommuted a full year before the residential relocation, then for only one quarter following the relocation, and then had no more episodes in the study period, our methodology would have assigned this person the causal status of "telecommuting caused relocation," when, arguably, a more proper assignment would have been the status of "telecommute quitter," because the individual essentially quit telecommuting following the move. In addition to simply looking at the single preceding quarter and the single following quarter, we informally examined multiple quarters before and after relocations. Table 6 shows that taking a longer period into account would not change a significant number of the causal assignments. Perhaps three moves, found in records 1030, 5005, and 5035, would arguably warrant having their causal status changed—to NY (from YY), YY (from NY), and YY (from YN), respectively. Changing these classifications impacts the results very little; the substance of the findings is not affected (see Ory and Mokhtarian, 2005, for further discussion of this issue).

STATED IMPORTANCE OF TELECOMMUTING

Our third method of analysis examines the stated importance of telecommuting to residential relocations. The survey instrument directly inquires about the importance of telecommuting to residential moves. Specifically, respondents could state that having the ability to telecommute was "most important," "important," "somewhat important," or "not at all important" in each of their previous three residential relocations. We can then examine whether a high reported importance of telecommuting translates into a residential location more distant from the workplace. As discussed in the Introduction, these responses may be biased toward exaggerating the importance of telecommuting.

Table 7 presents the responses for the stated importance of telecommuting to the residential move decision, segmented by the causal groups presented in the previous section. In addition to the number of moves in each cell, the average change in commute length is presented.

Table 7 suggests that, despite the presumed bias in favor, telecommuting does not play a very important role in residential relocation. Out of a total of 179 relocations, only 11 times did respondents rate the role of telecommuting as "the most important factor" (2 times), "important" (5), or "somewhat important" (4). Even among the 15 moves for which temporal precedence suggests a causal role for telecommuting (the "Yes, Yes" column), it is given some degree of importance to the move in fewer than half (7) of the cases—supporting the discussion in the Introduction of the point that temporal precedence by itself does not establish causality. However, those within that segment were considerably more likely to credit telecommuting than those who did not telecommute before the move, but did so following the move (2 of the 13 cases in the "No, Yes" group). This result is consistent with the assumed direction of causality, based on the timing of the move and the telecommuting engagement, made in the previous section. Also, the average changes in commute length for those respondents reinforce the previous unexpected result, that those who relocated their residence due to the ability to telecommute *reduced* their commute, on average. Of course, as noted earlier, the temporal precedence rule is also flawed in the sense that the actual timing of the *decision* (as

TABLE 7. STATED IMPORTANCE OF TELECOMMUTING IN RESIDENTIAL RELOCATION DECISION[a]

Stated role of telecommuting in decision to move	No, No (control)	No, Yes (relocation → telecommuting)	Yes, Yes (telecommuting → relocation)	Total
Not telecommuting at the time				
N	16	3	1	20
Change in commute length (miles)	4.25	–9.67	5.00	2.20
Not at all important				
N	16	7	7	30
Change in commute length (miles)	–0.05	4.00	0.00	0.80
Somewhat important				
N	0	0	4	4
Change in commute length (miles)	–	–	–11.50	–11.50
Important				
N	0	2	2	4
Change in commute length (miles)	–	48.50	–4.00	22.25
The most important factor				
N	1[b]	0	1	2
Change in commute length (miles)	–20.00	–	–7.00	–13.50
All (including Never Telecommuter responses[c])				
N	150	13	15	178
Change in commute length (miles)	1.17	14.54	–3.73	1.73

[a]"No, Yes" means not telecommuting the quarter before the move and telecommuting the quarter after, and so on. The "Yes, No" group, which contained only one observation, is omitted here. [b]We speculate that a telecommuting experience more than one quarter before the move influenced the move. [c]In addition to the Never Telecommuters, this category also includes those Ever Telecommuters who did not answer the question on the role of telecommuting in their move (which accounts for the differences in this row and the sum across the preceding five rows).

opposed to the action) to telecommute and/or relocate is not known. As shown in Table 7, the two respondents in the "No, Yes" (relocation causes telecommuting) column who stated that telecommuting was "important" to their moves (even though they apparently did not start telecommuting until after the move) may be erroneously labeled by the temporal precedence methodology, which looks at the action (not the decision) of telecommuting and relocating. Because the average change in commute length for these two respondents is very high (48.50 miles), reassigning them to the opposing causal group could significantly change the results and present telecommuting as more of a potential "foe" to travel reduction policies.

Also of interest is the relationship between the change in average commute length and the stated importance of telecommuting on residential relocations, independent of the telecommuting status. The final column in Table 7 summarizes the average change in commute length and number of responses across the causal groups. No obvious relationship exists between the average commute length change and the stated importance of

telecommuting to the move. Those who were not telecommuting at the time of their residential relocation, or who placed no importance on telecommuting to their move, increased their commute length by about the overall average, and those who placed an importance on the ability to telecommute did not uniformly move closer to or farther from work. Thus, whatever the *stated* role of telecommuting may have been, its *actual* impact on residential location appears to be neutral at worst.

CONCLUSION

This paper presents an empirical examination of the causal relationship between telecommuting and residential relocation. The key question we attempt to answer is whether telecommuting is a "friend or foe" of travel reduction policies. In the friend scenario, telecommuting allows those independently inclined to live in distant locations to commute less frequently to work. In the foe scenario, telecommuting motivates those who would otherwise live closer to work to move to more distant locations, possibly increasing urban sprawl and resulting in more vehicle-miles traveled than would have occurred without the option of telecommuting.

The examination presented here used data from a 10-year retrospective survey of 218 State of California workers, including current, former, and non-telecommuters. We first confirmed that telecommuters are, in fact, putting more distance (and travel time) between their homes and workplaces than are non-telecommuters. While these results are not statistically robust due to the small sample size, they do provide suggestive evidence, and support further investigation into the causal nature of those observed differences.

Two additional methods were then used to examine the causal relationship between telecommuting engagement and residential relocation. First, the timing of the moves in relation to the timing of the telecommuting engagement was examined. Here, it is inferred that the ability to telecommute caused a relocation if an individual telecommuted directly before and after the move. Conversely, it is inferred that the relocation caused the telecommuting engagement if an individual began telecommuting following relocation. Those who neither telecommute before nor after the move are used as the control group, and those who telecommute before relocation, but not afterward (labeled as telecommute quitters) are assigned to neither causal group. This analysis revealed that those who are inferred to have their residential relocation caused by telecommuting unexpectedly *reduce* their commute duration and length, on average. Conversely, those who are inferred to have telecommuting caused by their relocation substantially increase their one-way commute duration (by approximately 15 minutes) and length (18 miles). These results suggest that, on average, those who are inspired to move because of telecommuting are moving closer to work (or that the temporal relationship is largely coincidental, although as discussed below, the result holds even for moves in which telecommuting was directly reported to be important), while those who relocate far from work are afterward inspired to telecommute.

The second method of causal analysis examined the stated reasons for residential relocations as captured by the survey instrument. In this analysis, the timing of the moves is again examined, this time in relation to the stated importance of telecommuting to the relocation. Here, although cell sizes are small, the results are consistent with the causal inferences made based on temporal precedence, in that those who are inferred to have

their relocation caused by the ability to telecommute rated such an ability to be an "important" (to some degree) factor in their residential move more than those who are inferred to have their telecommuting caused by their residential move. Again, however, moves for the former group tended to *reduce* commute lengths. There was no relationship between the stated "importance" of telecommuting in residential relocation decisions and the resulting actual change in commute length.

The results presented here more strongly support the hypothesis that telecommuting is a "friend" of travel reduction policies, with telecommuting more often following, rather than preceding, the relocations that lengthen the commute. Together with the finding from previous analysis of these data, that telecommuters' commute person-miles traveled is no worse than that of non-telecommuters' despite their longer one-way commute lengths (Mokhtarian et al., 2004), it appears that (at least for now) policymakers need not fear substantial "rebound effects" from telecommuting programs directed at salaried employees.

Given the limitations of our retrospective survey design and small sample, however, continued monitoring of the long-term impacts of telecommuting is clearly desirable. Ideally, future studies should perform a similar set of analyses on a larger sample of individuals, tracked over time, rather than surveyed retrospectively. Having a full range of sociodemographic and attitudinal data at each quarter, or other time interval, would allow for more complex and interesting analyses, including the impacts of telecommuting engagement on transportation attitudes through time; finer estimation of the relationship between telecommuting engagement and commute characteristics (i.e., after accounting for changes in income, lifestyle, etc., what role does telecommuting play?); and a mapping of telecommuting patterns of individuals over time (do they lose interest in telecommuting?). It would also be desirable to extend a similar analysis to home-based business owners.

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