The Journal of
Regional
Analysis
& Policy

JRAP (2003)33:1

The Effect of Telecommuting on Suburbanization: Empirical Evidence

Kala Seetharam Sridhar and Varadharajan Sridhar[1]

Abstract. In the standard urban model, employment is concentrated in the Central Business District (CBD) and the locational choice of households is modeled solely on access to the employment center. Now, technology has facilitated the emergence of new office environments where work is done at unconventional locations that were earlier in the CBD. While the urban density function is not really new, in this study, we look at the effect of telecommuting, made possible by technology, on suburbanization, using data for U.S. metropolitan areas. We use population and household gradients as measures of suburbanization. For telecommuting indicators, we use data from Survey of Income Program and Participation (SIPP). We find support for the natural evolution theory of suburbanization. We find that telecommuting contributes to centralization of cities. We conclude that technology could be a complement, not a substitute for face-to-face interaction.

1. Introduction

The suburbanization of metropolitan areas in the United States has drawn a lot of attention of the researchers (Mills and Price 1984; Mills 1992; Margo 1992; Mieszkowski and Mills 1993). Suburbanization is the process where, holding constant population, the percentage of population in the suburbs rises. Standard urban economic theory shows that increases in income and population have the effect of increasing suburbanization. In the "computer-mediated economy" (Varian 2001), however, the influence technology could have on suburbanization has received little attention. Recent literature (Gasper and Glaeser 1998; Negroponte 1995) makes general conclusions about how technology may eventually cause a decline in the need for urban concentration. They prognosticate how improvement in telecom-

[1] The authors are currently faculty at the Indian Institute of Management, Lucknow, India. Kala Seetharam Sridhar, Business Environment Group, Indian Institute of Management, Prabandh Nagar, Off Sitapur Road, Lucknow 226 013, India. Phone: (91) (522) 2361 891, Ext.560, E-mail: kala@iiml.ac.in and Varadharajan Sridhar, Information Technology and Systems Group, Phone: (91) (522) 2361 891, Ext.547, E-mail: sridhar@iiml.ac.in

munications will create a "spaceless world" and affect the growth and spread of urban areas.

Improvements in telecommunications and computer connectivity that can allow people to work from remote locations can be best characterized as technological change. It is easy to see how the merging of computers and telecommunications technologies has greatly facilitated people to communicate effectively across geographically dispersed locations. The growth of the Internet has made it possible for organizations to interconnect people. Advances in wireless technologies have increased mobility of individuals and the ability to work from remote locations, and hence to locate further away from the Central Business District (CBD) where their offices are located.

1.1 Telecommuting

By definition, telecommuting is the process of commuting to work through communication links rather than through one's physical presence. Telecommuting refers to working at home, and in non-traditional satellite offices, in telecottages[2], or in neighbourhood offices, as discussed in Shin, Sheng and Higa (2000). Teleworking refers to the partial or complete substitution of telecommunications technology for the trip to and from the work place. Computers, connectivity to the Internet, fax, cellular phones, and advanced communications services such as Integrated Services Digital Network (ISDN) and high-speed dial-up access services have removed the physical barriers that formerly required employees to be always in their offices.

Telecommuting has potential to benefit urban areas, employers, employees and society. The benefits of telecommuting for urban areas can be substantial if they reduce long rush-hour commutes and congestion. Telecommuting increases employee productivity by reducing the need to travel by allowing them to work at times they are likely to be at their best, and by reducing office distractions. Recently, National Panasonic found through its research that 50 percent of employee time in branch offices was spent on administrative work that was non-productive. It is now looking at the small office home office (SOHO) concept as one of the measures to increase productivity in the times to come.[3] The Economic Times (July 21, 2002) reports that in the U.K., 2.5 hours are added to work-related journeys each week because of congestion. Recently, British Telecom (BT) increased the use of phone conferencing among its staff in the U.K. by 30 percent. Currently at BT, 75 percent of all phone conferences are replacements for face-to-face meetings. A study that looked at the impact of this decision found that BT reduced carbon dioxide emissions by 54,000 tonnes this year, besides a sav-

---

[2] Telecottages are those established in rural areas to provide access to information technology for a variety of purposes.

[3] "No more morning rush, office is at home" The Economic Times, April 2, 2001, Bennett, Coleman & Co. Ltd.

ing of 12 million litres of car fuel, costing an estimated 9.7 million pounds, due to reduction of a staggering 220 million miles of travel and 1,800 years of staff time over the past year.

Telecommuting not only benefits employees but also organizations that can cut costs related to office space. As Egan (1997) points out, IBM recently reported savings of $75 million in real estate expenses related to office space because of telecommuting. Also, companies' choice of talent gets widened to even "mobility-impaired" talent. Contrary to perception, telecommuting could also increase employee participation in organizational activity. BT found that the average conference call involved 8 participants, whereas if face-to-face meetings were held, only 5 traveled on an average.[4]

1.2 Estimates of Telecommuting

According to the Gartner Group, as of 2002, more than 108 million users world-wide are working outside the boundaries of their enterprise. Evidence of such teleworking has been found in India (Irani, Gothoskar and Sharma 2000; Mitter 2000) and Malaysia (Ng and Jin 2000). Estimates for European countries vary for teleworkers of all types at 4 percent of the workforce (Pancucci 1995). Kurland and Egan (1999) point out that estimates of the number of telecommuters in the U.S. vary and range between 3 and 9 million people, roughly 3 to 8 percent of the workforce. Forecasts for the U.S. for the year 2000 vary considerably, as Kurland and Egan (1999) summarize from various studies, from 15 million workers to 44 million workers to 57 percent of the workforce. Handy and Mokhtarian (1995) point out that while it is possible that telecommuting levels vary across states, the national level for telecommuting is not substantial. They point out that by 2002 the penetration rate of telecommuting may vary between 5.2 and 10.4 percent of the workforce compared to the very low levels of about 1.6 percent projected for 1996.

A Forrester Research study points out that about 10 percent of U.S. households maintain a second office at home, bringing home about 9 hours of work per week. Two-thirds of them have specifically bought a PC to help them work at home, and 64 percent access the Internet from home. The synergism between telecommuting and office automation has been documented through cases in Watad and DiSanzo (2000).

Shin, Sheng and Higa (2000) discuss that most of the empirical studies on teleworking conducted in the United States and Europe were predicated on home-based work. On the other hand, those implemented in Japan collected data primarily from satellite offices or in local offices. Since, in this study, we are interested in the effects of telecommuting on urban patterns in the U.S., we confine ourselves to the narrow definition of telecommuting that results from working from home.

---

[4] "Ringing in healthier ways" The Economic Times, July 21, 2002, Bennett, Coleman & Co. Ltd.

In this study, we look at the effect of telecommuting on suburbanization. In the standard urban model, employment is concentrated in the CBD and the locational choice of households is modelled solely on access to the employment center.[5] However, technology has now facilitated the emergence of new office environments where work is done at locations other than conventional offices normally located in the CBD. Households are now not constrained in their location decision by proximity to the CBD. So, while households that locate farther from the CBD, are still compensated by lower costs of housing, they need not incur higher conventional commuting costs, thanks to technology that has made remote working and suburbanization more plausible.

The findings from the research will also help us analyze whether people prefer to live in suburbs and telecommute to work in the CBD if adequate telecommunications and information technologies are available.

In urban economic theory, the gradient is used as a measure of population suburbanization. The gradient shows how population density (number of persons per square mile) changes with distance from the CBD. Suburbanization is the process that occurs when the absolute value of the gradient falls. While the urban density function is not really new, in this paper, we examine whether telecommuting increases suburbanization by reducing the need of population / households to commute to the CBD for work.

The rest of the study is organized as follows: in section two, we review the literature on suburbanization and telecommuting; then we discuss the data used and a detailed explanation of the model developed in the study in section 3; the data sources are presented in section 4; analysis of the data and results from the estimations are presented in section 5; and remarks and future research direction conclude the study.

2. Literature Review

McDonald (1989) provides a survey of the literature on density functions. A more recent literature review on studies of gradients is in Anas, Arnott and Small (1998). Broadly, one stream of literature on traditional urban models relies on the natural evolution theory and takes into account the impact of income and population on the density gradient. The literature dealing with the natural evolution theory of suburbanization shows that income growth leads to decreases in the gradient (Margo 1992). The theory suggests that as new housing is built at the periphery of cities, high income groups that prefer larger amounts of housing settle there. Another factor that sup-

[5] It is easy to conceive cities that have multiple employment centers. However, as long as employment density in the CBD is greater than it is in the suburbs, the monocentric urban model is still used.

ports the natural evolution theory is that, over time, increases in real income make expensive modes of transportation, like the automobile, more affordable. Second, larger metropolitan areas are more suburbanized than smaller ones (Mills and Price 1984; Mieszkowski and Mills 1993). Suburbanization is known to occur in large metro areas because of retail services and lower land costs in the suburbs. That is, as the metro area becomes larger, households prefer to move to the suburbs to make use of shopping malls and consume greater amounts of housing than what would be available in the CBD.

A second class of explanations of suburbanization in the literature stem from the Tiebout model that relates suburbanization to central city problems such as high taxes, poor educational attainment, racial tensions, and poor quality of public services. This literature relies on "flight from blight" and argues that central city problems are the cause of the increasing suburbanization observed in the United States. Mills and Price (1984) made an attempt to look at the "flight from blight" hypothesis. Their empirical finding was that the set of measures representing central city problems -- crime, educational attainment, and taxes -- however adds nothing to our understanding of population and employment suburbanization.

As Mieszkowski and Mills (1993) point out, even if the effect of "flight from blight" is relatively small, it could have considerable effect on the margin because the measurement of gradients is on an exponential scale rather than a linear one. For example, an absolute change of 0.05 in the density gradient in the range 0.20 to 0.25 is quite significant. As Mills and Hamilton (1989) calculate, in an MSA with central city radius of 8 miles and a density gradient of 0.20 (in our data set, Austin, TX and Columbus, Ohio are the metro areas that meet these criteria), 47.5 percent of its population lives in the central city. According to Mills and Hamilton, with a gradient of 0.25, the percentage living in the central city rises to 59 percent. Thus Mieszkowski and Mills (1993) point out that even if "flight from blight" is a relatively small explanation, it is an important factor affecting suburbanization and is a key factor to whether it is considered a manageable phenomenon or a problem. We concur with this and assume that the natural evolution and fiscal-social problem approaches are both important in explaining suburbanization.

Since the mid-1980s, a number of studies have looked at the impact of technology in favor of and against its advent. Research regarding the impact of information technology on urban form has focussed on agglomeration economies and transport costs. Giuliano (1998) is a preliminary attempt to understand how information technology (IT)-related changes in the organizational work may affect both commuting patterns and metropolitan form. He finds that commuting lengths are the shortest for self-employed, and full-time temporary workers have longer commutes, as one would expect. He does not find clear patterns of residential location distribution for permanent and temporary workers.

The major issue addressed by the transport literature is whether the greater effect of IT is a substitute or a complement to conventional travel. Mokhtarian and Henderson (1998) study commuting trips made by different groups of workers including telecommuters. They find that home-based telecommuters made 18 percent fewer trips and travelled 46 percent less than non-home-based workers. But they do not examine the effects of telecommuting on urban form.

In a recent study, Gaspar and Glaeser (1998) analyzed the effect of improvements in information and communication technologies on face-to-face interaction. They found that telecommunications may be considered a complement to, not really a substitute for, cities and face-to-face interactions. They examined micro-level data and the impact of basic technology such as telephones on face-to-face interaction and found that telephone calls between two households located closer increase with face-to-face interaction. This shows that technology and face-to-face interaction are not substitutes, but complements to each other. Also, with the advent of video and teleconferencing since the mid-1980s, can we expect a reduction in business travel? No. That is the answer provided by Gaspar and Glaeser based on U.S. business travel data which found that even after adjusting for cost changes, business travel in the United States registered a substantial increase since the advent of technology. This again supports that technology and face-to-face interaction are complements rather than substitutes.

While we do not examine patterns of commuting for various groups of workers, we extend the analysis of suburbanization and examine if telecommuting made possible by technology, has some impact on urban form and increases the suburbanization of metropolitan areas by reducing the need to commute to work daily. This research is thus an attempt to fill the gap in the literature.

In a report by the Office of Technology Assessment (OTA, 1995), it has also been reported that little work has been done to characterize and compare telecommunications infrastructure across the United States at the metropolitan level. Most of the studies, as also indicated in Nunn and Warren (1997), suffer from lack of data in spatial terms. Thus there is a lack of sufficient empirical research in areas of telecommuting mainly due to data limitations. This study overcomes the data limitation by making use of data published by the U.S. Department of Commerce as part of the Current Population Reports in Survey of Income Program and Participation (SIPP), wave 4 (1996), that contains information on whether or not workers worked from home on one or more days of the week. We aggregate this data by MSA. We supplement this with data from the 1997 supplement of the Current Population Survey (CPS) that contains a number of relevant questions relating to

Computer Ownership / Internet that are best characterized as infrastructure enabling telecommuting, and for their use at home for doing office-related work. This study examines these data for all the metropolitan areas of the United States to examine the impact of telecommuting on suburbanization.

3. Data and the Model

Our database consists of data on suburbanization, telecommuting, and other socio-demographic characteristics of households for the metropolitan areas of the United States defined by the United States Office of Management and Budget (OMB).

3.1 Suburbanization Indicators

There are several criteria that are needed for an appropriate measure of suburbanization (Mills 1992). We use the gradient as a measure of suburbanization. This is because it has several advantages. The first is that the gradient approach is relatively simple. As Mieszkowski and Mills (1993) point out, the exponential density function is a reduced form equation of a simple and robust model of metropolitan spatial organization.

After a nearly exhaustive literature search on gradients, we found that no study has, so far, estimated gradients for all MSAs in the United States using data at the census tract level. It is quite data intensive to estimate density gradients.[6] Getting around this data problem, Mills' two-point gradient technique enables us to calculate the gradient based on just 4 data points for every MSA- -central city and metro area boundaries, and their populations. We use Mills' two-point gradient technique to calculate gradients for all the metropolitan areas of the United States.

Define L_C (population of central city), L (population of metro area), R_C (radius of central city), and R (radius of metro area), data on which are available for all MSAs. Although data on the radius of central city and of the metro area are not readily available, the area, in square miles of the central city and metro area, is available from the United States Bureau of the Census. Making the assumption that the metro area is circular in shape, we solve for its radius.[7] The circular city assumption is not unrealistic if we take into account the fact that all metro areas have a circular highway as their outer loop that defines their boundaries.

The standard exponential density function, as proposed by Mills (1972), is:

---

[6] Data that are required to estimate density gradients are population density (per square mile) for census tracts and their distances from the city center, for all MSAs. The gradient is the coefficient in a regression of density (for census tracts) on distance from the city center. In this approach, as may be clear, this regression is required for every MSA.

[7]Since the area of a circle is ΠR^2, R (radius of circle) is easily solved for.

$$D(r) = D_0 e^{-br} \quad (1)$$

where D (r) is density r miles from the center, e is the base of the natural logarithm, and b and D_0 are constants estimated from the data, if they are available at such a disaggregated level (usually census-tract level).

From the theoretical exponential density function in equation (1), we derive the ratio of L_C to L as given below:

$$\frac{L_C}{L} = \frac{1 - e^{-bR_C} - bR_C e^{-bR_C}}{1 - e^{-bR} - bR\ e^{-bR}} \ . \quad (2)$$

Given data on L_C, R_C, L, and R, we calculate the gradient b in (2) for all the U.S. metropolitan areas.[8]

As we indicated earlier, we are not aware of any other study that has estimated gradients for all the metro areas of the U.S. and studies that have estimated *household* (not *population*) gradients. It has to be remembered that the urban model is really a household, not a population model. The variables that have been taken into account in the literature - - taxes, public services including better schools, safety - - affect household locational behavior as much as they affect population behavior. These hypotheses, however, have not been systematically tested in density studies. Here we calculate a gradient based on the households, in addition to the one based on population. We measure households by the number of housing units for which data are available from the United States Bureau of the Census.

3.2 Methodology: Model of Suburbanization

Variables chosen to explain changes in the gradient include telecommuting indicators, along with those that represent the natural evolution theory and the "flight from blight" hypothesis, as we have indicated earlier. A generic model which illustrates the relationship between suburbanization as indicated by the slope of the density function b and the independent variables can be written as: $b_i = f(\alpha_i, \beta_i, \gamma_i)$, where b_i is the population / household gradient of the i^{th} metropolitan area; a_i refers to a set of factors indicated by natural evolution theory and includes population, and per capita income; b_i refers to factors indicated by the "flight from blight" hypothesis and includes social and demographic factors such as relative levels of education and proportion of nonwhite population in the central city when compared to suburbs of the ith metro area; γ_i refers to telecommuting indicators.

[8] We calculate the gradient using the software Visual Basic.

In addition to the telecommuting indicators, we control for the proportion of employment in the metropolitan area that is in computer and data processing services because we assume that it is this category of employment in which employees are likely to telecommute. In fact, the summary report released by the U.S. Department of Commerce regarding home-based workers in the United States points out that "..the (telecommuter) population is likely to expand and draw increasing attention as the information economy continues to develop" (U.S. Department of Commerce 2001, p.6). Since an important component of the information economy is in computer and data processing services, we assume that this category of employment is best associated with telecommuting.

3.3 Measurement of Telecommuting Indicators

Here we choose indicators that represent telecommuting and those that enable telecommuting. The latter refer to infrastructure such as access to computer and the Internet.

3.3.1 Telecommuting Indicators

We have indicated earlier that the standard monocentric model is based on the assumption that heads of households commute everyday to their jobs in the CBD. In this process, they incur commuting costs. Based on this, we may conjecture that if a worker telecommutes during at least some of the workdays, s/he can cut down on costly commuting trips and move his/her residence further away from the CBD. Thus the idea of commuting trip reduction is critical to what we examine here.

Consistent with the idea of commuting trip reduction, we have chosen the proportion of full- and part-time workers that worked at home on at least one of the days of the week (Monday through Friday) in their primary job, as telecommuters. This data is available in SIPP, wave 4, in the 1996 supplement. We have sampled only those workers that worked at home at least 1 full day a week, but also worked other days in a location outside of their home, in their primary job, for all MSAs (these telecommuters are called "mixed workers" in SIPP). In fact, SIPP makes it possible for the first time to document the calendar patterns of telecommuting. An Appendix contains the questions that form the basis for our representation of telecommuters.

There is also data available in SIPP on non-home workers who are defined as those that did not a work even a full workday at home as part of their work schedule, again by MSA. These are best characterized as non-home-based workers, or as those workers conventionally commuting to work. Telecommuters (PROPMW) are defined by taking mixed workers as a proportion of mixed and non-home-based workers.[9]

Data is also available in SIPP on home-based workers, but we did not include them in the computation of telecommuters because that confuses the issue. First, it is not clear what the characteristics of these purely home-based workers are. They could be self-employed, in which case their location choice does not depend on where they work anyway.[10] Only if they have a factory or a customer visit, for instance, which they need to make will their household location choice depends on where the factory would be located. This is not very clear in the data either. Second, the work of 'home-based' workers at home does not lead to any additional trip reduction. Because of these problems, we excluded home-based workers from our analysis and in the computation of the proportion of telecommuters.

3.3.2 Infrastructure Indicators

Working from home or telecommuting, in fact, requires communication and exchange of files and messages between workers' home and the organization. A typical home office set-up requires a computer for performing office automation tasks. Nunn and Warren (1997) argue that the capacity of metropolitan areas to use information technology relies on the presence of a computer literate population with computers as much as on phones and telecommunications infrastructure. An analysis using technology (such as point-to-point or multi-point telephone call) as a replacement for face-to-face meetings in a virtual organization is presented in Gasper and Glaeser (1998). Today, most of the organizations use the Internet for facilitating communication. This is also dependent on employees being able to use computers and Internet at their home for effective telecommuting.

To estimate the infrastructure that enables telecommuting, we measured availability of computers and Internet at home, from data available in the 1997 Internet Usage Data Supplement (IUDS 1997), published by the Bureau of Labour Statistics as supplements to the Current Population Survey (CPS). The Appendix contains the questions from these supplements that form the

---

[9] Since SIPP makes it possible to document calendar patterns of telecommuting, we also used a measure that reflects the average number of telecommuting days (as proportion of the week) in place of the proportion of telecommuters we have reported in the estimations. One would expect that if telecommuters in an MSA telecommuted four times a week, on average, such MSAs would be more suburbanized than MSAs in which telecommuters telecommuted only once a week. We found that the average number of telecommuting days did not have a statistically significant impact on the extent of suburbanization, whereas the proportion of telecommuters had a positive and statistically significant impact on the gradient.

[10] It is possible that growth of the information economy has made home-based self-employment more viable. But as we mention in the text, it is not clear from the data set what activity these self-employed workers are engaged in. Even in the case that home-based work is enabled by growth in the information economy, such work does not result in any reduction in conventional travel, so we did not include self-employed, home-based workers in the analysis.

basis for these supporting variables we have used here. In addition to questions on computer ownership / Internet access, relevant data that were available in IUDS 1997 were whether he / she uses the Internet at home for purposes of job-related tasks.[11] We take the use of Internet at home (IUSE-HOME) for work, as an alternative indicator of telecommuting.[12]

3.4 The Model

We regress b, the population / household gradient, calculated from equation [2], on the variable set α_i, β_i and γ_i. When controlled for the relevant factors, it is our expectation that MSAs with higher proportion of telecommuters will be more suburbanized or, specifically, have a lower absolute value of the gradient. That is, metropolitan areas where people telecommute would be more suburbanized. This means that people would prefer to live in suburban areas even if their employment were located in the CBD. If it were to be found that the proportion of telecommuters has a negative impact on the gradient (make it smaller), this research would confirm that electronic exchange of information is in fact a substitute for face-to-face interaction, as Gasper and Glaeser (1998) surmised.

4. Data Sources and Other Variables

The data sources for the calculation of the gradient and other independent variables come primarily from the 1990 United States Census of Population. The data on central city and suburb land area (the Census does not use the term "suburb," instead it uses the term "outside the central city"), used in the calculation of R_C and R, are from the 1990 United States Census of Population: Population and Housing Unit Counts. At the time this research was done the central city and suburb population counts for 2000 were not available. So we estimated 2000 central city and metro area populations, L_C, and L, based on "Population Estimates for Metro Areas and Components,

---

[11] These questions are asked in IUDS 1997 of all persons. We have taken only the household head into account by isolating the unique ID for all responses within a household. It is possible that there are two-worker HHs for which both need to telecommute to affect their location decision. But in that case, we would have to restrict ourselves only to such HHs (in which both head and spouse are both working) which would make the sample further small in some cities. We thus aggregated the responses of all responding household heads to these questions at the level of the metropolitan area.

[12] It should be noted that the mere use of computer or the Internet at home for office-related work by itself is not a robust indicator of telecommuting that is a substitute for the trip to and from the workplace. It is possible that a number of employees bring home some of their work for the evenings and weekends and this is probably captured in these data. But our primary interest is look at those that actually reduce their actual trips to the workplace because of their work at home. The proportion of mixed workers which we use is thus a more robust indicator of telecommuting since it involves commuting trip reduction and this could be important in influencing suburbanization.

Annual Time Series, April 1, 1990-July 1, 1999, published by the Population Division, United States Bureau of the Census. The data (L_C, R_C, L and R) for the 264 metropolitan areas of the United States are substituted in equation [2] and the population (POPGRAD) and household gradients (HHGRAD) are solved for 2000. The use of 1990 data for R_C and R is reasonable because the size of metro areas do not rapidly change. Over a decade, even if the radii would change, such changes would be marginal. Thus we assume that R_C and R remained more or less constant for the metro areas over 1990-2000.

For calculation of the household gradient (HHGRAD), only data on 1990 housing units were available at the time this research was carried out. Assuming that the average HH size has not substantially changed over the period 1990-2000, we calculated the ratio of households (measured by number of housing units in the central city and the metro area) to population in 1990 and applied this ratio to the estimated 2000 population for the metro areas to estimate households for 2000.

Data on metropolitan area per capita income (PCI), percentage of population with high-school degrees (used as a measure of educational attainment) (EDURATIO), percentage nonwhite in central city and suburb (NONWHIT), are from the 1990 United States Census: Summary of Social and Economic Characteristics. In the case of educational attainment, the ratio of the proportion (of persons >25) with high-school degrees in the central city to that in the suburbs is used. Similarly, in the case of racial composition, the ratio of the proportion nonwhite in central city to that in the suburb is used.

Property tax rates are calculated based on property tax revenues and assessed value of taxable property data for county areas that comprise central cities and suburbs of metropolitan areas. Even here, the ratio of property tax rates (TAXRATIO) in the central city to that in the suburbs is used. The use of ratios thus avoids problems of differing relative sizes of central cities and suburbs (or county areas that comprise central cities and suburbs). Data on property tax revenue by county areas are taken from Government Finances, Vol. 4, No. 5, "Compendium of Government Finances," published as part of the 1990 United States Census of Governments. Data on taxable property values by county area are taken from Taxable Property Values, Vol. 2, No. 1, "Assessed Valuations for Local General Property Taxation," published again as part of the 1990 United States Census of Governments.

For purposes of calculating this variable, we first determined the county areas that comprise the metropolitan areas (based on data available from the Office of Management and Budget in the document Metropolitan Areas and Components, 1990 with FIPS Codes).[13] Since county areas are the local gov-

[13] Although the 6 New England states are defined using sub-divisions of counties referred to as towns and cities, data on property tax revenue were available only for county areas (even in the

ernments that collect property taxes in most cases, this assumption is appropriate. Then we determined, based on flags in the data, which of these county areas contained the central city and which were outlying counties. We have confirmed that outlying counties to metropolitan areas typically are included as part of the metro area because they had sufficient automotive commuting ties with the central county, plus some other characteristics of an urban nature.

We took the ratio of property tax revenues to the total assessed value of taxable property (net of deductions) in county areas that contain the central city and determined this to be the central city property tax rate. We adopted a similar procedure to calculate property tax rates for suburbs. Then we took the ratio of property tax rate in the central city to that in the suburb. In cases where the metropolitan area consisted of only one county, we determined that the property tax rate ratio would be 1, implying that central city and suburban property tax rates are the same. This is a valid assumption because in these cases, it is possible that commuting takes place from within the county from the edge of the metro area to its CBD.

For calculating the metro area's proportion of employment in computer and data processing services, we obtained 1997 data on the total private employment in all industries and Standard Industrial Classification (SIC) code 737 from Bureau of Labor Statistics covered employment and wages program.[14] The ratio of SIC 737 employment to total private employment in all industries is determined as the proportion of technology employment (TECHEMP) in the various metro areas.[15]

New England states), although data on assessed value of property were available for cities. Because of this limitation, we used the ratio of county area tax rates for cities in New England states too.

[14] The following are the categories of employment included in SIC 737 (Computer and data processing services):
SIC 7371 Computer programming services
SIC 7372 Prepackaged software
SIC 7373 Computer integrated systems design
SIC 7374 Data processing and preparation
SIC 7375 Information retrieval services
SIC 7376 Computer facilities management
SIC 7377 Computer rental & leasing
SIC 7378 Computer maintenance & repair
SIC 7379 Computer related services, not elsewhere classified.

[15] In fact, to determine whether or not technology employment in the various metro areas were centralized or suburbanized, we tried to get data on employment in SIC 737 (Computer and data processing services), for central cities and 'outside of central city' of the MSAs, so that we could use ratio of %technology employment in central city to that in the suburb, as we have done for other variables. However, such disaggregated data are not available either for SIC 737 or total (private) employment.

5. Data Analysis

As indicated earlier, the location decision at an individual level might be aggregated to collective location decisions, and we have examined the density function to look at household in addition to population suburbanization.

We calculated population and household gradients for all the 264 metro areas of the U.S. Estimation is based on a sub-sample (60) of MSAs for which all data on the independent variables were available.[16] We describe these data in Table 1 for the sub-sample.

Table 1. Descriptive Statistics for Data (N=60)

	Average	Standard Deviation	Maximum	Minimum
Population gradient	0.2329	0.1019	0.4774	0.0733
Household gradient	0.2426	0.1067	0.5056	0.0819
Population of metro	1,014,470	772,543	3,857,097	251,199
Metro Per capita income	$14,124	$2,013	$19,937	$6,630
% Technology employment	1.19%	0.99%	6.08%	0.05%
Ratio of non-white in central city to that in suburbs	4.04	3.02	11.82	0.76
Ratio of property tax rate in central to that in suburbs	1.30	1.11	9.36	0.30
Ratio of those with high-school degree in central city to those in suburbs	0.98	0.11	1.35	0.80
Proportion in metro telecommuting at least one day Mon-Fri	2.80%	1.58%	7.32%	0.45%
Proportion in metro with Internet access at home	55%	12%	76%	17%
Proportion using Internet at home for work related purposes	32%	8%	51%	10%

The descriptive statistics for two gradients - - one based on population and the other based on households, are provided in Table 1. The population (POPGRAD) and household (HHGRAD) gradients move almost perfectly together with a correlation of 0.99 (Table 2). This shows that population and household location decisions are almost identical. This is surprising because we expect HH location decisions to be based on additional factors like quality of schools, besides proximity to work, which would be probably the primary consideration for the population (assuming"persons" rather than households).

[16] All data were available only for 61 out of 264 MSAs, SIPP being the primary limitation. There was a clear outlier in the PROPMW variable (this was Daytona Beach FL, MSA) we had to remove.

The average value of the population gradient testifies to the continuing suburbanization of American cities. Edmonston (1975) applied Mills' method of two-point estimates to a sample of 41 cities that were metropolitan districts in 1900 and found that the average density gradient was constant at 0.8 between 1900 and 1920. Between 1920 and 1930 the average gradient fell to 0.66 and between 1940 and 1950 it fell significantly from 0.61 to 0.39. In a similar trend, Table 1 shows that in 1990, the average population gradient for American cities fell to 0.23 indicating further suburbanization.

The most centralized metropolitan areas (based on the population and household gradients of 0.48 and 0.51 respectively) are Eugene-Springfield, OR and Reading, PA. We have checked other studies that have estimated density gradients for 1970, 1980, and 1990 (Jordan, Ross and Usowski 1998). They do not estimate gradients for these metro areas.

At this point, a suitable limitation of the two-point technique has to be kept in mind. It is possible that estimates of gradients for small urban areas such as Reading, PA are biased upwards, because two-point estimates of an exponential form for a city with a small area[17] force the population / household density to decline quickly and yield high densities close to the center.

The most suburbanized metropolitan area is Atlanta, GA. Note that Atlanta, GA is also the largest metro area in the sample. Compared to the density gradient of 0.098 Jordan, Ross and Usowski (1998) computed for Atlanta, for 1990, we find further suburbanization of this metro in 2000. There is a negative and significant correlation between the population gradient and population (see Table 2). Large metro areas suburbanize primarily to make use of retail services and also to make use of lower land costs in the suburbs.

On average, telecommuters (PROPMW) form only 3 percent of the population (Table 1). This is consistent with the estimate (1.6%) of telecommuting projected by Handy and Mokhtarian (1995) for 1996.[18]

Compared to this estimate of telecommuting from SIPP, we can see from Table 1, based on IUDS 1997, that on average, nearly one-third of households (heads) reported using the Internet at home for working on office-related tasks. This indicates that all these households are not telecommuters and at least some of them were conventional commuters that brought home some of their excess office work for evenings and / or weekends, lending support to the fact that the mixed worker variable is a more robust indicator of telecommuting.

When we looked at the infrastructure variables that enable telecommuting, in the data for the 60 MSAs, interestingly, we found that all households

---

[17] For instance, Reading's land area is only 859.20 square miles compared to 5,121 square miles for Atlanta, GA MSA.

[18] Recall that the telecommuter data we have used also belongs to 1996 from SIPP.

that were interviewed had at least one PC at home. We therefore used the proportion of households with Internet access from their home as an indicator of infrastructure enabling telecommuting. We find that on average, nearly 55 percent of households in the MSAs had access to the Internet (PROPINT) from PCs in their home. This suggests that technology infrastructure may not be a constraint for telecommuting.[19]

We find that on average, the proportion of technology employment (TECHEMP) was still quite small as of 1997, averaging around 1.2 percent of total employment (with the highest proportion (6%) of technology employment in Provo-Orem, UT). The small numbers for technology employment lend support to the low proportion of telecommuters observed in the data. This is because we assume that employment in technology-related occupations (see footnote 13 for a description of these industries) provides enough flexibility for telecommuting, which is quite reasonable to believe. One could argue that the proportion of employment in technology-related services is not the only source of possible telecommuting. All organizations are resorting to computerization of their routine start-up and maintenance operations (for example, there are probably few companies in the United States that do not have presence on the web). But our conjecture is that in these non-technology companies, IT-related services would not be the primary activity to the extent that would involve telecommuting. The correlation between TECHEMP and PROPMW is positive, although not significant (Table 2).

The ratio of the nonwhite variable (NONWHIT) shows that on average, central cities of metropolitan areas contain four times as much nonwhite population as their suburbs, with the highest nonwhite population in the central city being in Milwaukee, WI. The average property tax ratio (TAXRATIO) being greater than one indicates that on average, central city property tax rates are greater than suburban rates, and provide some rationale for the “flight from blight” hypothesis. On average, the ratio of educational attainment (EDURATIO) in the central city when compared to that in the suburbs shows that typical central cities have a lower proportion of high-school graduates than their suburban counterparts. All these variables provide support for the “flight from central city blight” hypothesis.

We looked at the correlation between the population / HH gradient and PROPMW for preliminary test of any correlation between telecommuting and suburbanization. We found this correlation to be positive and significant. This indicates that MSAs with higher number of telecommuters also are more centralized. We discuss details of this relationship below, where we present the regression results.

---

[19] It is possible that the speed of Internet access, in addition to access, is important in enabling telecommuting. However, in the U.S., this is not a constraint, since high-speed access technologies such as ISDN and DSL are available in most urban areas.

5.1 Results from Estimation

We estimated separate regressions of the dependence of the population and the household gradients (suburbanization), to test the impact of natural evolution theory, the "flight from blight" hypotheses, and telecommuting (Tables 3 and 4). We estimated different specifications of the model, using alternative indicators of telecommuting for which we had data. The "flight from blight" variables and population / income variables (indicated by the natural evolution theory) are common to all models. The difference between the models is that they contain variants of the telecommuting variables.

The variables POP / 100,000 and PCI / 10,000 are indicators of the natural evolution theory. The variables NONWHIT, TAXRATIO and EDURATIO indicate central city blight conditions relative to that in suburbs. TECHEMP is a control variable to watch for technology employment. The PROPINT variable is used as the infrastructure variable enabling telecommuting from home. Finally, PROPMW is used as the telecommuting variable to examine its impact on suburbanization.

The regression results in Table 3, based on both the population and household gradients, support the natural evolution theory. They show that large cities (those with large populations) are likely to be more suburbanized than their smaller counterparts, when we control for the influence of central city fiscal and socio-demographic characteristics. This is consistent with the theory, and evidence found by Mills and Price (1984). The theory shows that in large metro areas, suburbanization occurs primarily to make use of lower land costs in the suburbs.

Table 3. Estimation of Population and Household Suburbanization Dependent Variable: Population and Household Gradients (N=60)

Coefficients of:	Population Gradient	t value	Household Gradient	t value
Intercept	0.4389	2.08	0.4846	2.13
Pop / 100,000	-0.0078	-4.83*	-0.0080	-4.59*
PCI / 10,000	-0.0624	-0.99	-0.0680	-1.00
TECHEMP	0.0098	0.87	0.0090	0.74
NONWHIT	-0.0003	-0.06	0.0002	0.03
TAXRATIO	0.0037	0.38	0.0045	0.42
EDURATIO	-0.0911	-0.65	-0.1118	-0.74
PROPMW	0.0128	1.82**	0.0116	1.53
PROPINT	-0.0013	-0.02	-0.0097	-0.10
Adjusted R^2	**0.39**		**0.36**	
F	**5.76**		**5.06**	

*Statistically significant at 1 percent level.
**Statistically significant at 10 percent level.

We had hypothesized that MSAs with higher proportion of telecommuters were likely to be more suburbanized. The telecommuter variable, PROPMW, has a positive effect on both population and household suburbanization and significantly impacts population suburbanization. This indicates that the greater the proportion of telecommuters in MSAs, the greater the extent of centralization, and the lower the proportion of telecommuters, lower the extent of centralization. This suggests that technology and cities / face-to-face interactions are complementary, not substitutes.

It could well be the case that technology employment has suburbanized to make use of skills of the suburban labour force. But even if technology employment were concentrated in one or few suburbs, as it is in the case of the I-270 technology corridor in Rockville, MD, a suburb of the Washington, DC metropolitan area, suburban residences tend to spread out across suburban space to make use of lower land costs, as suburbs also get gradually congested. This makes telecommuting important. Thus one may realize that as long as physical distances remain, telecommuting also is important.

One way in which telecommuting is made possible is through the use of the Internet and email. The availability of the Internet at home (PROPINT), the infrastructure-enabling indicator variable, has the expected negative impact on the population and household gradients, but is not statistically significant at the traditionally accepted levels. We had expected that the higher the proportion of population with access to the Internet, higher would be the extent to which population has the flexibility to locate farther away from the center where offices are located, and so the MSA would be more suburbanized.

The proportion nonwhite has the expected negative impact on the gradient, lending possible support to the "flight from blight" hypothesis, but is not statistically significant. Low relative taxes and the presence of an educated population in the suburbs have repellent effects in both the population and household gradient regressions, but are not significant.

We estimated different specifications of the model we have presented here.[20] We estimated the regression taking into account the proportion of just full-time workers (those that worked at least 40 hours a week) that were telecommuting, and eliminated the part-time workers that were telecommuting, included in Table 3. We found that the full-time worker-telecommuter variable was positive, but not significant, in affecting the population or household gradients. All other variables remained the same in their effect on population and household suburbanization. The population variable (POP / 100,000) continued to remain significant and had the expected negative effect on population and household suburbanization in all these models.

Next, we used an alternative indicator of telecommuting we obtained from IUDS 1997 (IUSEHOME), which refers to the proportion of households

---

[20]We did tests of heteroscedasticity to check for the possibility of non-constant variability of the extent of suburbanization with size of cities, which is frequently a problem with cross-sectional data. However, we found no evidence of this. We used the Goldfeld-Quandt test and failed to reject the assumption of homoscedasticity.

that use the Internet at home for job-related tasks (Table 4). Table 4 includes the same variables in the estimation, but replaces the telecommuter variable PROPMW, with the alternative indicator of telecommuting, IUSEHOME. We continue to find support for the natural evolution theory, with the sign on population significant and as expected, being negative. The per capita income variable becomes more significant than in the earlier specification now, and is negative as expected, but is not significant at the conventionally accepted levels. We expect PCI to have a negative effect on the gradient because increases in income make the automobile more affordable and suburbanization more plausible.

Table 4. Estimation of Population and Household Suburbanization, Using an Alternative Indicator of Telecommuting [Dependent Variable: Population and Household Gradients (N=60)]

Coefficients of:	Population Gradient	t value	Household Gradient	t value
Intercept	0.4833	2.25	0.5060	2.21
Pop / 100,000	-0.0085	-5.31*	-0.0085	-5.00*
PCI / 10,000	-0.0742	-1.17	-0.0817	-1.21
TECHEMP	0.0109	0.95	0.0092	0.75
NONWHIT	0.0009	0.21	0.0013	0.27
TAXRATIO	0.0049	0.49	0.0052	0.48
EDURATIO	-0.0997	-0.69	-0.1151	-0.75
IUSEHOME	0.0455	0.33	0.0864	0.58
Adjusted R^2	**0.37**		**0.34**	
F	**5.87**		**5.39**	

*Statistically significant at 1 percent level.

We find that the alternative indicator of telecommuting, IUSEHOME, is not significant. We had expected this to have a negative effect on suburbanization. That is, higher is the proportion of population that uses the Internet from home for office-related work, greater would be the flexibility to locate farther away from the CBD and greater would be the extent of suburbanization. None of the other variables are significant in the population or the household gradient regressions in Table 4, as in the earlier specifications, except population, which continues to have the expected negative effect on population and household suburbanization.

The model in all cases is a better explanation of variations occurring in the population gradient rather than the household gradient, as may be seen in the value for the adjusted R^2 reported in Tables 3 and 4.

It may be seen that the result that remains robust in all specifications is the impact of population on suburbanization. Among the technology variables, we have found that telecommuters actually live closer to the CBD.

Our preferred specification of the model is what we have presented in Table 3. This is because we believe that PROPMW is the most robust indicator of telecommuting. The alternative indicator of telecommuting we have used in Table 4, IUSEHOME, could be biased especially if full-time conventional workers bring home part of their office work. In this case, their use of the Internet from home for office-related work will not result in any reduction in their conventional trips to the workplace. In all such cases, this measure cannot be considered a good proxy for telecommuting.

5.2 Discussion of Results and Implications

The positive and significant impact of the telecommuting variable on suburbanization in the preferred model implies that telecommuting might actually persuade population / households to locate closer to the CBD and increase centralization of cities. This means that holding everything else constant, higher proportions of telecommuters cause population density to be higher near the CBD, and vice-versa. This suggests that telecommunications and technology are not a substitute for face-to-face interaction and cities, as we may conjecture, but rather a complement, consistent with the findings of Gaspar and Glaeser (1998).

The results we find are consistent with other literature (Kurland and Egan 1999) that accepts some limitations of telecommuting from an organizational perspective and the need for constant monitoring, which could explain why telecommuting could increase centralization. Employee telecommuting implies remote supervision that presents monitoring challenges for the employer, while physical isolation may impede the employee's involvement in determining valued organizational outcomes. It might also make it difficult for the company to ensure the quality of its services and their delivery time (Mitter 2000). Giuliano (1998) finds that the potential effects of information technology in promoting spatial dispersion are constrained by technical and institutional barriers. As Ng and Jin (2000) point out, telecommuting entails a significant change in management culture, trust on the part of employers, motivation on the part of employees, teamwork, and networking.

If these broader organizational changes take place, then it is possible that telecommuting can lead to increased suburbanization. If the broader organizational issues are addressed, telecommuting can also be a productive way of engaging women and other minorities in the labour force since they may not be able to participate in the labour market otherwise. Thus the extent to which technology influences spatial patterns depends on the adoption and use of technology by individuals and institutions.

5.3 Limitations and Areas of Future Research

Finally, we need to qualify limitations of the work to enable better understanding of the results and their implications. First, we have to note that, our sample in addition to being small (consisting of only 60 MSAs for which we could find relevant data from SIPP), excludes tech-savvy cities like San Jose, CA, and large cities like New York and Los Angeles, CA; MSA, that could change the results we have found here. There was no data in SIPP on mixed workers for a number of important MSAs including these. In fact, lack of overlap of data for the telecommuting and socio-demographic variables, was the constraint in expanding the sample.

Second, the data is based on a small number of observations in some metro areas that could be a problem. Another possible data caveat is that the population and household gradients are calculated for 2000 whereas the SIPP data are for 1996. We also assume that central city and metro area remained more or less constant over 1990-2000. We do not expect the gradient (and geographical areas) to change overnight or rapidly from time to time. So the time period may not be a constraint in explaining the results.

Finally, note that calculation of the gradient and examining the impact of telecommuting on this gradient entails the assumption of a monocentric model consisting of only one central business district where all employment is concentrated. It is easy to conceive that cities have multiple employment centers including those in suburbs. As long as employment density in the CBD is greater than it is in the suburbs, the monocentric urban model still is used. We also have to remember that the gradient is the coefficient in a regression of density (for census tracts) on distance from a central point, usually the city center. It may not make much sense to calculate such gradients for distances from all employment centers to the edge of city.

Further, if data were to be available regarding employment in SIC 737 (Computer and data processing services), for central cities and "outside of central city" of the MSAs, we can compute ratio of %technology employment in central city to that in the suburb, as we have done for other variables. So far, such disaggregated data are not available either for SIC 737 or total (private) employment. If this data were available, we could assess more accurately the contribution of technology-enabled services to population suburbanization by enabling them to reduce their conventional trips to the workplace.

It is important to note that telecommuting need not be always home-based. As Mitter (2000) points out, teleworking will gradually progress to include mobile workers such as sales people, telemarketers with mobile phones or those telemarketing from home, or those that work on multiple sites, such as maintenance workers. The common characteristic of all these workers could be that they increase flexibility in the location of work and reduce workers' commuting time, wherever they are. Another area of future research is to look at the proportion of all such workers, if the data were to become available, in urban areas and examine their impact on urban form, using the gradient approach used here or other approaches used in the literature, summarized earlier.

6. Concluding Remarks

This study throws light on basic data regarding employees that worked at home on at least some of the days of the work week, and the access of Internet of households from their PCs at home. Our data also sheds light on the usage of Internet for working from home. The infrastructure data we looked at (computers and Internet access at home) enabled us to conclude that they are not a constraint for telecommuting. The question we have answered is not whether employees wish to telecommute if adequate technology is available, but whether we can foresee purely virtual organizations and greatly suburbanized cities. The answer is no.

There is no question about the influence of technology that has suburbanized U.S. offices such as call centers to international work locations. The most important implication of this research is that population and household location choices, and their impact on urbanization patterns, are complex. After all, technology may not be a good substitute for face-to-face organizational interaction.

References

Anas, A., R. Arnott, and K. Small. 1998. "Urban Spatial Structure." *Journal of Economic Literature*. 36 (September): 1426-1464.

Berendt, A. 1998. "The Virtual Enterprise Gets Real." *Telecommunications (International Edition)*. 32 (4): 32-36.

Edmonston, B. 1975. *Population Distribution in American Cities.* Lexington, MA: D.C.Heath.

Egan, B. 1997. "Feasibility and Cost Benefit Analysis." Paper presented at the International Telework Association Annual International Conference, Crystal City, VA (June).

Gasper, J. and E.L. Glaeser. 1998. "Information Technology and the Future of Cities." *Journal of Urban Economics*. 43: 136-156.

Guiliano, G. 1998. "Information Technology, Work Patterns and Intra-Metropolitan Location: A Case Study." *Urban Studies*. 35 (7): 1077-1095.

Handy, S. and P. Mokhtarian. 1995. "Planning for Telecommuting." *Journal of American Planning* Association. 61 (1): 99-111.

Irani, A., Sujata Gothoskar, J.C.Sharma. 2000. "Potential and Prevalence of Teleworking in Mumbai." *Economic and Political Weekly*. June 24, pp. 2269-2276.

Jordan, S. John P. Ross and Kurt Usowski. 1998. "U.S. Suburbanization in the 1980s." *Regional Science and Urban Economics*. 28: 611-627.

Kurland, Nancy B. and Terri D. Egan. 1999. "Telecommuting: Justice and Control in the Virtual Organization." *Organization Science*. 10(4): 500-513.

Margo, R. 1992. "Explaining the Postwar Suburbanization of Population in the United States: The Role of Income." *Journal of Urban Economics*. 31: 301-310.

McDonald, J. 1989. "Econometric Studies of Urban Population Densities: A Survey." *Journal of Urban Economics*. 26: 361-385.

Mieszkowski, Peter and Edwin Mills. 1993. "The Causes of Metropolitan Suburbanization." *Journal of Economic Perspectives*. 7 (3): 135-147.

Mills, Edwin. 1992. "The Measurement and Determinants of Suburbanization." *Journal of Urban Economics*. 32: 377-387.

____ and B.Hamilton. 1989. *Urban Economics*. Glenview: Scott, Foresman and Company.

____ and R.Price. 1984. "Metropolitan Suburbanization and Central City Problems." *Journal of Urban Economics*. 15: 1-17.

Mills, Edwin. 1972. *Studies in the Structure of Urban Economy*. Baltimore: Johns Hopkins Press.

Mitter, S. 2000. "Teleworking and Teletrade in India: Combining Diverse Perspectives and Visions." *Economic and Political Weekly*. June 24, pp.2241-2252.

Mokhtarian, P. and Dennis Henderson. 1998. "Analyzing the Travel Behavior of Home-Based Workers in the 1991 CALTRANS Statewide Travel Survey." *Journal of Transportation and Statistics* (October): 25-40.

Negroponte N. 1995. *Being Digital*. New York: Vintage Books.

Ng, C. and Khoo Khay, Jin. 2000. "Teleworkign in Malaysia: Issues and Prospects." *Economic and Political Weekly*, June 24, pp. 238-2313.

Nunn, S. and R. Warren. 1997. "Metropolitan Computer Services Infrastructure and Economic Development Capacity in the Information Society." *Economic Development Quarterly* 11 (4): 329-346.

Office of Technology Assessment (OTA), U.S. Congress. 1995. *The Technological Reshaping of Metropolitan America (OTA Publication No. ETI-643)*. Washington, DC.

Pancucci, D. 1995. "Remote Control." *Management Today*. April, pp.78.

Shin, B., O. Sheng and K. Higa. 2000. "Telework: Existing Research and Future Directions." *Journal of Organizational Computing and Electronic Commerce*. 10(2), 85-101.

United States Bureau of Labor Statistics. 1997. *Internet Usage Data Supplement (IUD)* http://www.bls.census.gov/cps/computer/1997/sdata.htm.

United States Department of Commerce. 2001. "Home-Based Workers in the United States: 1997." *Household Economic Studies* (P70-78): 1-7.

United States Department of Commerce. 1996. *Survey of Income Program and Participation (SIPP)*, Wave 4, 1996 supplement, http://www.sipp.census.gov/sipp.

Varian, Hal. 2001. "The Computer-Mediated Economy." *Communications of the ACM*, (March): 93.

Watad, M. and F.J. DiSanzo. 2000. "Case Study: The Synergism of Telecommuting and Office Automation." *Sloan Management Review* (Winter): 85-96.

Appendix

Relevant Questions from SIPP 1997

Variable	Description	Question
EWSHMWK1	Worked at home at job 1	As part of the work schedule for that week, were there any days when …. Worked only at home for (employer of Job 1)?
EWSDY11,.. EWSDY17	Worked at home on Sunday, .., Saturday at Job 1	Whether …. Worked at home on Sunday, .., Saturday during that typical week

The universe of respondents for variables **EWDY11, .., EWSDY 17**, is persons s15+ who held a job or business in month 4 of the reference period.

The variable PROPMW is taken as all those that worked at home at least one weekday (Monday through Friday), in addition to a location outside of home on other days.

Telecommuting Questions in Internet Usage Data Supplement (UIDS) 1997

Variable	Description	Question
PESCU1	Computer-in household, y/n	Is there a computer in this household?
PESCU4L (PROPINT)	Computer-has internet connection, y/n	Which of the following items does the [/newest] computer have? Does it have a (n) Internet connection?
PES11G (IUSEHOME)	Internet use (home) job related tasks – y/n	Does … REGULARLY use the internet to do job-related tasks?