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Suits or pajamas: an economic analysis of the causes and consequences of telecommuting

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Honors Thesis in Economics

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Professor Tietenberg

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Abstract

While the concept is not new, the popularity of telecommuting has increased with the expansion in telecommunications and technology through the last twenty years. Telecommuting, or the ability to work away from one's regular office site, is now easier than ever to do with the advancements in reliable telephone systems, personal computers, and Internet access that allow one to go to the office virtually rather than physically. This concept has gained the attention of policymakers and public planners because of its potential to address various issues, possibly leading to a better quality of life, increased productivity, and improved air quality. This study examines the economic causes and consequences of telecommuting by first looking at what factors cause people to telecommute and then determining the potential consequences of its increasing popularity. While there is no typical telecommuter, there seem to be several common factors among workers that choose to do so. Telecommuting has the potential to produce many benefits for society; however, determining whether it will ever realize its potential is still unclear.

I. Introduction

After sitting in deadlocked traffic day after day, one begins to wonder whether there is a better way of getting to work. In recent years, commute times have been getting longer, often making one frustrated and worn out even before the work day begins. While suburban dwellers may spend up to an hour or more each day sitting in their cars waiting for the nearest bumper to inch forward, many metropolitan workers spend their commute times waiting on subway platforms or in crowded subway cars and
buses (http://www.census.gov). For some, this commute time provides a needed buffer zone between one’s personal and business lives; more crowded highways and longer commute times, however, have begun to mitigate the benefits received from that time alone.

The United States population continues to grow each year, reaching a mark of over 281 million Americans in the Census 2000 report (http://www.census.gov). As a result, the demand for highway use and public transportation, particularly at peak times, is a growing concern not likely to be solved in the near future. Public policymakers and administrators have thus begun to seek methods for alleviating this concern, looking toward any means by which to decrease highway and transportation demands.

Following the lasting booms in telecommunications and technology over the last twenty years, alternative methods for addressing these concerns have gained popularity. During this expansionary period, the traditional methods of conducting business have changed dramatically. Although the technology and Internet boom has slowed its course, the many business practices developed during that time are here to stay. Advanced telecommunications, the Internet, and e-mail have improved efficiency in the workplace and brought convenience to the home. After a long day at the office, the ability to bring one’s laptop home, sign-on to the Internet, and finish work-related tasks at home instead of staying late at the office is an increasingly attractive means of doing business. Similarly, the potential to spend more time at home has lured many to complete such work-related tasks at home for a full business day rather than just after hours. More than ever before, the possibility of working from home, or telecommuting, is a viable alternative to going to the office every day.
Similarly, reliable telephone lines (with accurate speaker-phone and conference-call capabilities), personal computers, and high-speed Internet connections allow employees to go to the office virtually rather than physically. As a result, many individuals and corporations have begun to telecommute with increased frequency. In recent years, telecommuting has thus attracted the attention of policymakers because of its potential to alleviate travel demand through either decreasing the overall number of commuters or delaying some commuters' travel times to spread out beyond peak times.

This concept of working from home is not new; professionals such as consultants and investment bankers have conducted business from their homes via facsimile and telephone for years. Additionally, doctors have treated patients at home and lawyers have brought home case work. What is new, however, is the increasing number of telecommuters in recent years and the economic motivations to telecommute that exist today. Recent technology has allowed a wider variety of occupations to maintain telecommuting with little or no decrease in work quality. Employees can seamlessly conduct business from home as if one were physically in the office. Now, there is little reason why a tax consultant at a Big Five accounting firm could not work from home one day each week rather than drive to the office.

This study will examine the economic causes and consequences of telecommuting. While working from home may have once only seemed like the perfect opportunity to participate in a conference call in one's pajamas, telecommuting is now a legitimate means of conducting business. Specifically, this paper will illustrate why employees decide to telecommute and why employers allow their workers to do so. Presumably, employers and employees have different reasons for participating in
Telecommuting programs; likewise, a group of individuals or employers may also have
different reasons among them for participating. Additionally, different industries may be
more likely to promote telecommuting, as such programs may affect a company's bottom
line in different ways; individuals with certain personalities or lifestyles may also be
more likely to telecommute.

This study, therefore, will focus on three aspects of telecommuting. First, it will
examine the economic causes of telecommuting, for both workers and employers.
Specifically, this paper will examine why and when telecommuting occurs. It will
discuss what kinds of people telecommute, employee perceptions of telecommuting, the
motivations for telecommuting, and the costs and benefits of telecommuting. Workers
and employers may have different reasons for embracing telecommuting, and this paper
will determine how these reasons differ and how they interact.

This paper will then investigate the economic consequences of telecommuting.
That is, after establishing the variables that affect the decision to telecommute, this study
will analyze the current and future effects of telecommuting. Employers would be
interested in learning whether telecommuting can improve productivity and affect their
bottom line; similarly, workers would benefit from knowing whether telecommuting can
help balance their demanding business and personal lives. Furthermore, many public
collectors are interested in the potential telecommuting has to help reduce traffic
congestion or even improve air quality. Learning whether telecommuting can be a
valuable tool for fighting such problems is an issue currently gaining momentum among
state and local municipalities.
Finally, this paper will investigate the future trends and outlook of telecommuting as it relates to the potential consequences of its implementation. Many are interested in the possible transportation impacts of telecommuting and learning where the direction of telecommuting is headed into the future.

Although the amount of resources and information available on telecommuting is extensive, little economic or empirical research has been conducted; much of the resources are focused toward telecommuting issues, productivity gains, and anecdotal experiences. As discussed by Shin et al. (1995), much of the existing research on telecommuting is not guided by theories or hypotheses and lacks empirical analyses. As a result, this study is a great opportunity to examine an existing topic in a new fashion.

Interest in telecommuting has increased in recent years because it is a topic that appeals to many sectors. Workers, employers, policymakers and public planners would all be interested in this research. Telecommuting has the potential to address many different issues—possibly leading to a better quality of life, increased productivity, and improved air quality. Policymakers would be interested in understanding whether telecommuting could have environmental or transportation effects. For example, if the number of telecommuters increases over time, roadway congestion may decrease significantly such that carbon dioxide emissions are substantially reduced. Similarly, company executives would be interested in learning whether telecommuting can improve a company’s bottom line or help to retain and recruit valuable employees. As a result, many look forward to learning more about the effects of telecommuting and determining whether it will ever realize its potential. This research will examine the issues behind telecommuting and help explain its economic causes, consequences, and future outlook.
This paper begins with a description of the background and history of telecommuting in the following section and continues with a review of previous literature in section III; section IV describes the sources of data. The model hypothesis of the economic causes of telecommuting is developed in section V, followed by its results and interpretation. Section VII illustrates the model hypothesis of the economic consequences of telecommuting, and its results are followed in the subsequent section. These results will be used to examine the future trends of telecommuting by discussing its transportation impacts and future outlook. As much of the previous study on telecommuting varies greatly and lacks empirical analysis, the extensions and limitations of this research will be discussed in section IX. The final section will conclude this paper, followed by an appendix with all relevant data and regression results referred to in this paper.

II. Background and History

The many studies and resources available on telecommuting often use different expressions to describe the concept—one study or website may use a different definition from another. As a result, the definition of what constitutes a telecommuter is often left to interpretation. This section, therefore, will serve to further explain the terms surrounding telecommuting as well as give a brief history of its evolution and describe its common perceptions.

While each study may have its own criteria, most research loosely defines telecommuting as occurring whenever an employee is paid for work done at an alternative worksite to the traditional office such that total commuting time is thereby
reduced (Mariani, 2000). Alternative worksites can essentially be anywhere—such as satellite offices or telecenters—but it usually consists of one’s home. Within the definition of telecommuting, most studies will exclude self-employed workers and employees who take work home without additional pay. That is, people who set up their own business from home or lawyers who take home extra case work to read over dinner are not generally considered telecommuters. Telecommuting must also occur during normal business hours such that work at the traditional worksite is reduced.

In addition to its definition, the amount of telecommuting also varies among studies. Although once considered to only occur fulltime, in reality telecommuting has evolved to be practiced more sporadically. A worker no longer needs to work at home full time to be considered a telecommuter. While some research includes telecommuters as those workers that telecommute at least once a week, others include those workers that do so only once a month. In general, however, telecommuters are workers who telecommute at least once a week and up to a few times each month.

In addition to telecommuting, the term telework is often used in the literature, and as a result, has created a great deal of inconsistency—as well as confusion. As described by Shin et al. (1995) telework is often viewed as encompassing intra-organizational functions (such as telecommuting and mobile work) and inter-organizational functions (such as electronic data exchange). That is, telework includes any type of distributed work arrangement enabled by information technology, such as telecommuting. Many researchers describe something similar. According to Jala International, Inc., telework is “any form of substitution of information technologies (such as telecommunications and/or computers) for work-related travel” (http://www.jala.com). Telecommuting,
however, is more specific and entails periodic work outside the principal office either at home or in telecenters so that a reduction in or elimination of commuting time is realized.

Despite the semantics, the terms telecommuting and telework are often used interchangeably with little regard to their more specific meanings. For example, Gil Gordon illustrates that the word telework is more often used in Europe, whereas telecommuting is more popular in the U.S. (http://www.gilgordon.com). For the purposes of this paper, no distinction will be made between the two terms, unless otherwise noted, and the expressions will be used interchangeably.

Despite what many may believe, telecommuting did not arise from the growth of technology and the Internet during the 1990s, although it did gain popularity due to the increased ease with which one could participate. As noted by the U.S. Census Bureau (1998), the recent surge in the popularity of telecommuting began in the 1980s, prior to widespread Internet use, and reversed an earlier trend of declining work performed at home.

The idea that telecommunications technology could substitute for travel or commuting has been around for a long time, as many ideas sprung up following the invention of the telephone (Mokhtarian, 1997). In the 1870s, numerous articles discussed the potential of the telephone to substitute face-to-face contact. As further noted by Mokhtarian (1997), H.G. Wells described videoconferencing, or "kineto-telephotographs," in 1899. One of the first individuals to foresee the coming of telework was Norbert Wiener in his book *The Human Use of Human Beings: Cybernetics and Society*, published in the 1950s, (U.S. Department of Transportation [DOT], 1992). In his book,
Wiener envisioned an architect living in Europe participating in the construction of a building in the United States, following the introduction of the new Ultrafax service. These ideas focusing on the substitution of travel and commuting with telecommunications technology resurfaced in the 1960s and 70s, as advances in computing technology progressed and the energy crises initiated efforts to reduce energy-related consumption. At the time, telecommuting also gained popularity because of terminal-based computers and voice-quality phone lines that enabled alternative work arrangements to become more practical (DOT, 1992).

Generally considered the "father of telecommuting and telework," Jack Nilles, founder of Jala International, Inc., coined the terms telecommuting and telework in 1973. During the 1970s and 80s, many writers predicted that major portions of the working population would be working from home by the end of the twentieth century (DOT, 1992). Since that time, however, most researchers have scaled back their predictions, but the promise and potential of telecommuting still remain high in the minds of many.

As noted by both Pratt (1999) and the DOT (1992), telework has evolved on an informal basis, generally through a bottom-up approach. Employees have led the innovation of telecommuting, usually by requesting to work at home during business hours, rather than employers through structured organizational-led programs. Today, telework is no longer a luxury for just a few privileged managers, but has evolved into an essential part of the modern work structure, helping employees to better balance their work and personal lives (Pratt, 1999). Large, formal telecommuting programs, however, continue to be in the minority, as most telecommuters participate on an informal or individual basis.
As noted by Shellenbarger (2002), the recent movement in telecommuting has morphed into broader mobility. The Internet boom has created new modes of telecommuting and helped evolve previous ones. Such new modes include wireless email while drinking coffee at Starbucks, videoconferencing from a Kinko's service center, and even working from telework centers in remote villages in India, served by wireless computers (Shellenbarger, 2002). In contrast to the early movements in telecommuting involving working from home, the most recent evolution in telecommuting encompasses work literally performed almost anywhere.

In accordance with the new trends in telecommuting and its greater acceptance, many of its common perceptions have begun to subside. Telecommuting is no longer associated with simple, full-time work at home, and now includes a variety of programs and initiatives. Despite this new trend, many still have perceptions of telecommuting that may not necessarily be accurate. As noted by Hartley (2001), many workers respond to the idea of telecommuting by thinking of the opportunity to work all day in their pajamas or believe that it must be a dream to work at home. Others automatically perceive that telecommuting is not for them, as they need to be in the office to get work done or desire to be more social. In sum, the perceptions of telecommuting can be either good or bad and still vary greatly despite its increased popularity.

While telecommuting has had a long history, its promise and potential have only increased in recent years, as many look forward to the effects that the telecommunications revolution can have (Shamir & Salomon, 1985). As further noted by Shamir & Salomon (1985), the impacts of telecommuting could be far-reaching as more people begin to work at home, affecting areas such as transportation, air pollution, energy
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consumption, labor markets and educational institutions. The impetus for this study has been the wide range of topics and issues that are addressed by the concept of telecommuting.

III. Literature Review

The amount of research conducted on telecommuting is extensive and numerous websites have been devoted to the further promotion, explanation, and implementation of telecommuting in the business world. However, many of these studies vary greatly in scope and even in some findings. The focus of various research reports tend to be in areas such as worker productivity or quality of life issues, and little empirical research has been conducted to determine the overall effects of telecommuting on various sectors of the economy or public policy. As will be discussed in the extensions and limitations section of this paper, the lack of strong empirical research is due largely to the fact that most telecommuters participate on an informal or individual basis rather than large, structured programs. As a result, determining the overall number of telecommuters is difficult to obtain accurately and such findings would greatly influence any potential impacts.

Most of the current literature focuses on the results of specific pilot programs or surveys, and this section will serve to illustrate the various findings discovered thus far about the implementation of telecommuting. In addition, this literature review will introduce the common variables and concepts affecting telecommuting, which will help lay the foundation for the economic causes and consequences of its increasing popularity. This review will first discuss the issues concerning employees, followed by those
affecting employers. Finally, this section will review the general issues of telecommuting, including any social, transportation, or environmental impacts that telecommuting may have.

a. Workers and Telecommuting

Among the numerous surveys and pilot programs initiated, many researchers have concluded that telecommuting can yield great personal benefits for workers. Both Mariani (2000) and the DOT have suggested that employees enjoy greater flexibility and reduced stress from telecommuting. The opportunity to forego a long commute in heavy traffic is relaxing and calms people's nerves. Workers enjoy the added ability to better balance their work and personal lives, as well as the reduced costs of transportation, food and clothing if more time is spent at home. For example, workers enjoy the greater ability to schedule a repair person (such as the cable or telephone company) to stop by the home during the day, similarly, workers are less likely to go out for lunch when working at home. A study conducted by Pratt (1999) revealed that 34% of telecommuters took time off from work to meet repair persons at home, while 49% left work during the day to attend to various legal or banking affairs. As will be discussed later in this section, telecommuting allows employers to take advantage of this lost time.

Such flexibility lets many workers spend more time with their families after business hours, as many home-related or personal chores can be taken care of during the day. In addition, Pratt (1999) found that 54% of teleworkers said they worked the same amount or more at home than they do in the office while also managing personal and home-related matters—that is a convincing display of the advantageous ability for many
workers to better balance their home and work lives more productively. As also noted by Szostak (1998) within the case of Fleet Financial Group, a telecommuting program improved the quality of life and efficiency of its employees, and workers were able to better integrate their work, family, and community lives. As a result, employees were happier and more focused, which led many to improved productivity by getting more work done in less time.

Furthermore, many workers are happier telecommuting because they enjoy various other perks particular to the home in addition to the previously noted benefits of shorter commute times. Hartley (2001) illustrated that at-home workers enjoy the ability to create their own surroundings with art or music, make their own coffee, and avoid office politics and infighting. Some telecommuters noted that they became closer to their spouses or children, making many workers happier. Pratt (1999) discovered that 55% of teleworkers involved in her study stated that they were more satisfied with their jobs after beginning to work from home than they were prior.

Some teleworkers, however, reveal some common disadvantages of working from home. Mariani (2000) found that many telecommuters tend to work straight into the night since their “office” is always close by and because at-home workers found it hard to differentiate between the end of the business day and the beginning of personal time. Additionally, while some teleworkers enjoyed the extra flexibility of attending to personal or home-related tasks during the business day, other telecommuters were easily distracted by the lure of unfinished home-improvement projects and other chores. And although telecommuting at home (as opposed to satellite offices) may help relieve the stress to find childcare, it is not a perfect substitute. Telecommuters must be able to
focus on work as if they were in the office, and nearby children are an easy distraction. Also, many children may not understand that even though their mother or father is home, they need to be left alone to concentrate.

As confirmed by Hartley (2001), teleworkers face other similar disadvantages. Telecommuting is not for everyone, as both strong self-discipline and initiative are needed to be successful when working at home since no boss or supervisor watches when one starts or stops work. Along the same lines, employees working at home or elsewhere are often out of sight from their supervisors but do not wish to be out of their minds. That is, many telecommuters feel as though they can be easily forgotten by coworkers in the office. For example, Lublin (2001) illustrated that it is easier for managers to walk down the hall in the office and give extra work to Johnny because he is visible, leaving telecommuters out of the loop. Shin et al. (1995) and Mokhtarian (1998) also found that some telecommuters fear social isolation and conflicts in career development, such as a slower promotion track.

In a different study, Shamir and Salomon (1985) discussed how work-at-home conditions can actually adversely affect the quality of working life. For many workers, social relations in the workplace are a primary source of job satisfaction, as the office provides an opportunity for social relations outside of the primary group of family and friends. They revealed that many middle-aged women with children indicate a desire for social relations as a significant motivation for seeking employment outside the home. For others, a workplace may be the only place for personal interaction with the opposite sex. Shamir and Salomon (1985) also discovered that unless outside social involvement is increased, a worker's quality of life can actually decrease while working at home. As
at-home workers may not often experience the popular “buffer zone” during commute times, some workers will carry stress between their work and personal lives. Similarly, dealing with conflicting demands of stress from home or work are more likely to occur simultaneously when spending more time at home.

Much of the previous literature has also tried to determine whether there is a typical telecommuter. As noted by Mariani (2000), there is not likely a general type of person that decides to telecommute, but most telecommuters are likely to work well independently, manage time well, have good communication skills, and be self-disciplined. Lublin (2001) discussed that strong networking skills are critical for telecommuters so that they can maintain strong ties to the firm even though they spend less time there. Mariani (2000) also mentioned that telecommuters usually spend some time working for an employer in the office proving themselves before beginning to telework; new employees are not usually hired to start telecommuting.

Certain jobs are also more likely to have greater telecommuting potential. Occupations requiring large blocks of uninterrupted time and concentration, or those that call for minimal special materials, are better equipped to handle teleworkers. However, Mariani (2000) also illustrated that virtually any job has some telecommuting potential, as most jobs have certain tasks or projects that can be done at home even if the job overall does not otherwise permit it on a regular basis.

In her survey, Pratt (1999) discovered that most telecommuters are typically married and well educated, with a majority being managers and professionals. The U.S. Census Bureau (1998) found that most at-home workers earn less money than, although many earn a great deal more than non telecommuters. Additionally, the Census report
found that 46% of at-home workers were in the services sector, including areas such as business and repair services.

Likewise, Mariani (2000) also revealed that most telecommuters were in the services industry, followed by manufacturing and wholesale trade. Among occupational groups, he found that the majority were professionals, as well as executives, administrators, and managers. Davis and Polonko (2001) confirmed Mariani's (2000) findings in their survey, discovering that most telecommuters work in professional or managerial occupations. They also illustrated that teleworkers are more likely to have higher education and income levels, as well as be male and from the Northeast and West.

While no typical telecommuter emerges—since most workers decide to telecommute for various personal reasons—the general literature suggests a few themes common among such workers. The model hypothesis in section V will further develop which factors are most important.

b. Employers and Telecommuting

While telecommuting can have mixed results for workers, most research has revealed that telecommuting can be beneficial for employers. When analyzing worker productivity, Pratt (1999) found that 47% of teleworkers say they are more productive when working at home, and such productivity increases were confirmed by Mariani (2000) and Verespej (2001).

As mentioned previously, telecommuting allows employees to attend to personal matters while also being able to work. Pratt (1999) discovered that many personal matters that cause employees to miss work only take two to four hours to complete, thus
leaving much of the day still available to work; telecommuting takes advantage of that
time and allows employees to be more productive under such circumstances. Many
teleworkers would have to take personal time or leave work early in order to meet
personal needs if they could not telework. The number of times workers need to be
absent from work is, therefore, reduced—yielding cost savings and benefits for
employers. For example, Pratt’s (1999) survey revealed that employers can save $2,086
per employee per year due to reduced absenteeism and save $1,850 per teleworker
annually from increased productivity. Similarly, Verespej (2001) also illustrated that
companies with telework programs can benefit from productivity gains and cost savings.
On average, companies experienced productivity gains of 22%, citing Cisco Systems Inc.
as one such example.

Verespej (2001), Hartley (2001), and the DOT also found that firms can benefit
from cost savings in other forms as well. Telecommuting can reduce real estate costs due
to the reduced need for office space, in addition to parking facilities and transportation
costs. In other words, companies can spend less money on such capital expenditures
when employing more telecommuters. Firms can also benefit from the use of
telecommuting to retain and recruit valuable employees (Mariani, 2000; Pratt, 1999;
Hartley, 2001). Pratt (1999) revealed that 53% of teleworkers indicated it would be
“important” or “extremely important” to have the ability to work from home when
considering a new employer. She also found that employers save $7,920 for each
teleworker retained because they do not have to find a replacement. (Such figures were
based on the general estimate that firms spend roughly one-third of an employee’s salary
to recruit him or her).
It is worth noting, however, that such gains in productivity and efficiency are not absolute certainties. As mentioned by Shin et al. (1995), measuring productivity is difficult, and workers and employers may have different methods to measure it. Many of these surveys also rely on self-reporting, leaving one to question the accuracy of such large gains in productivity. Despite these drawbacks, virtually every study or survey discussed the gains in productivity and efficiency, implying that such company benefits from productivity gains are likely even if the reported numbers may be exaggerated.

While the only main employer disadvantage to telecommuting discussed in the literature seems to be the ability to manage a more dispersed workforce, firms can significantly benefit overall from telecommuting initiatives through areas such as fewer capital expenditures, better employee recruitment and retention, and worker productivity gains (Mariani, 2000; Pratt, 1999).

c. Telecommuting in General

While the effects of telecommuting on workers or employers are relatively clear, the overall effects and impacts of telecommuting in general are not. Telecommuting is attractive to public policymakers and administrators because it is easy to implement, does not require large lead times, and has the potential to affect roadway congestion, air quality, and public transportation (DOT, 1992). As noted by Mokhtarian (1997), DOT (1992), and Gordon (1999), the reality of whether telecommuting can realize any of this potential is still quite unclear.

While many allude to telecommuting's great ability to reduce traffic congestion, Mokhtarian (1997, 1998) reveals several reasons why those benefits may not be great.
Although work is the most common reason for traveling on the roads, telecommuting will not necessarily remove a majority of cars from the roads. For example, people may take more trips to avoid cabin fever, do more shopping at the end of day, and drive alone to work (rather than carpool) on days they do not telecommute (Mokhtarian, 1997). Davis and Polonko (2001) found that teleworkers typically drive 5.7 to 18.6 miles per work day on errands, an amount certainly large enough to minimize the overall gains of decreased travel from fewer commuters. Trips normally performed en route to work, such as picking-up or dropping-off children, would still need to be taken (DOT, 1992). In other families, additional trips might be taken because an extra vehicle is made available by the family member telecommuting at home. Mokhtarian (1997) also noted that most teleworkers today live twice as far from work on average as others, meaning that the amount of vehicle miles saved will decrease as the number of telecommuters increase since distances will converge to the average.

Furthermore, workers may decide to undertake trips they otherwise would have avoided while commuting since they are spending more time at home and possibly have more free time (Mokhtarian, 1997). Less commuting might also urge people to move farther away from work, such that fewer commute days still equal the same number of total miles driven (Mokhtarian, 1998). The effects of eased congestion may be mitigated partially if non-telecommuters travel more due to freer highways. In other words, any freed transport capacity induced by telecommuting could be partially offset by others (Mokhtarian, 1998).

Many websites and research reports also wonder about the relationship telecommuting has with urban sprawl. As noted by Gordon (1999), determining such
causation is difficult and the realistic impacts of telework remain unclear. Gordon (1999) also mentioned that the amount of relocation as a result of telecommuting has not been large, although it is still a possibility since it could make long commute times more bearable if they are performed less frequently. In their comprehensive survey, Davis and Polonko (2001) discovered that roughly 30% of teleworkers changed residences; and of those teleworkers, 29% moved farther away from their employer while 52% actually moved closer to their place of employment.

Despite this evidence suggesting that telecommuting may not produce the large benefits some expect, it is also possible that telecommuting may, in fact, be beneficial and can reduce traffic congestion. Mokhtarian (1998) noted that roughly 1.5% of the workforce telecommutes on any given day, eliminating approximately 1% of the total household vehicle miles traveled. Likewise, Pratt (1999) found that telecommuting decreases round trip commuting by roughly 1,800 miles annually per teleworker. Mokhtarian (1998) also discussed that many workers may choose other activities, such as biking, running, or walking, instead of deciding to take extra trips in the car. This could be especially true if workers begin to live farther away from their places of work because they may not wish to spend additional time in the car on longer trips.

While acknowledging that the transportation impacts of telecommuting are uncertain, the DOT (1992) also mentioned that telework is likely to provide benefits in the form of better energy use, improved traffic congestion, and fewer vehicle miles traveled (VMT). Yet, determining such outcomes is difficult because estimates of the future levels of telecommuters is unclear. Any potential impacts are not only contingent upon such levels but also upon the numerous personal decisions taken by telecommuters,
such as additional shopping trips and residential relocations. Sections VII and VIII of this paper will discuss further the likelihood of the various impacts from telecommuting and their potential consequences.

In sum, the overall transportation impacts of telecommuting are still unclear, even as telecommuting continues to increase. Whether travel will actually increase or decrease is difficult to determine, since too many individual factors can influence such trends. However, most researchers have concluded that telecommuting is likely to improve traffic congestion, possibly leading to additional benefits such as improved air quality. This suggests that telecommuting is a means of conducting business worth encouraging even though the long-term effects are still unknown. A detailed analysis of the possible consequences of telecommuting will be discussed in sections VII and VIII, the model II hypothesis and results, respectively.

IV. Data Sources and Description

One of the most difficult aspects of this research has been determining the types and sources of data to use in order to investigate the causes and consequences of telecommuting. As discussed previously and as also noted by Pratt (1999) and Mariani (2000), telecommuting is not usually performed in structured programs, since most workers telecommute on an individual or informal basis. Additionally, 65% of telecommuters are employed by firms with less than 100 employees (International Telework Association & Council [ITAC], http://www.telecommute.org). Estimating the exact number of telecommuters in the United States is, therefore, a difficult task. Similarly, many researchers choose to define telecommuters differently from one another.
While some researchers, such as Pratt (1999), may define telecommuters as workers that telework at least one day each month, many others only consider telecommuters as those workers that telecommute at least once a week. Regardless of these definitions, most researchers at least agree that the average telecommuter participates about one or two times each week. This fact is helpful in better determining some of the impacts of telecommuting.

Recent trends in telecommuting have also made it difficult to determine the number of teleworkers. Shellenbarger (2002) and others have suggested that telecommuting has recently morphed into a concept of broader mobility. Many people now work on the road, from hotels and airports to Starbucks and Internet cafés. Tracking such employees is extremely difficult and has also caused confusion in the previous literature. Furthermore, Mokhtarian (1998) revealed that in one study 50% of telecommuters in a program quit within nine months; Shellenbarger (2002) illustrated that while up to one million workers begin telecommuting each year, almost as many return to the office annually. These issues make it difficult to decipher an accurate number of legitimate telecommuters.

Such difficulties and confusion have led researchers to widely varying estimates on the number of telecommuters. For example, according to ITAC there were approximately 8.5 million teleworkers in 1995 and up to 19.6 million in 1999. A more recent report performed by Davis and Polonko (2001), in conjunction with ITAC, revealed that there were 28 million telecommuters in 2001 that either worked at home, at telecenters and satellite offices, or on the road. A different survey conducted by the Gartner Group Inc. predicted over 30 million teleworkers by the year 2000, while
Cahners In-Stat Group revealed that the number of telecommuters increased from approximately 19 million in 2000 to 32 million in 2001, (http://www.gartner.com; http://www.instal.com;).

A table summarizing these estimates on the number of telecommuters is as follows:

**TABLE 1. NUMBER OF TELECOMMUTERS (MILLIONS)**

<table>
<thead>
<tr>
<th>STUDY</th>
<th>1995</th>
<th>1999</th>
<th>2000</th>
<th>2001</th>
</tr>
</thead>
<tbody>
<tr>
<td>ITAC</td>
<td>8.5</td>
<td>19.6</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Gartner Group</td>
<td></td>
<td></td>
<td>30</td>
<td></td>
</tr>
<tr>
<td>Davis &amp; Polonko</td>
<td></td>
<td></td>
<td></td>
<td>28</td>
</tr>
<tr>
<td>Cahners In-Stat</td>
<td></td>
<td>19</td>
<td></td>
<td>32</td>
</tr>
</tbody>
</table>

Although several of these figures seem to average around 30 million telecommuters in either 2000 or 2001, the seemingly small discrepancies reveal very different growth rates. Since Davis and Polonko (2001) suggested there were 28 million telecommuters in 2001 and Cahners predicted there were 32 million in the same year, it seems as though these researchers have concluded similar estimates. Cahners, however, estimated that there were 19 million teleworkers in 2000 while the Gartner Group predicted 30 million in that same year. In addition, some of these surveys define telecommuters as workers that participate at least one day per month, while others define them as workers that do so at least once a week; similarly, Davis and Polonko (2001) defined telecommuters broadly to include workers at satellite offices and on the road. These subtleties mask large differences in the actual number of telecommuters estimated.
in studies. While this definitional problem does not prevent one from predicting the
number of telecommuters, it does make it more difficult to determine whether researchers
agree on a similar estimate. As a result, choosing an estimate of the number of
telecommuters is important when examining the economic consequences of telework.
This decision will be discussed more closely in sections VII and VIII.

In addition to the difficulty in determining the number of telecommuters,
comprehensive and empirical data on telecommuting is not usually available. As
discussed previously, most research has not focused on quantitative analysis and relies on
the results from surveys and pilot programs. Furthermore, much of the literature on
telecommuting focuses on qualitative issues such as quality of life and worker
characteristics. Most of the comprehensive surveys tend to be proprietary reports and
analyses, making access to such information difficult. As a result, the ability to find
comprehensive data and the process of choosing the right data sets to analyze was an
obstacle early in this research process.

In light of these circumstances, I chose to use a more reliable and consistent data
set for my analysis of telecommuting. In order to examine the economic causes of
telecommuting, a 1994 report from the Department of Transportation (DOT) was used.
The report was very comprehensive and eliminated most of the problems with non­
empirical or proprietary studies. Many of these other studies consisted of surveys
conducted by private institutions and corporations, which could lead to certain biases.
Raw data sets for these other reports were also not typically available. The DOT data are
comprehensive, consistent, and of high quality.
The report consisted of data compiled from numerous urbanized areas within the U.S. as defined by the Census Bureau. The data include variables on 59 selected cities and metropolitan areas and are usually expressed as a percentage. That is, these data reflect percentages of workers (where applicable) in the elected metropolitan areas. For example, AT-HOME represents the percentage of workers that work from home in a particular city. The report included a variety of variables and allowed for numerous regression possibilities. The key variables used for the purposes of this study are as follows:

1. AT-HOME = Percent of workers age 16+ that work at home.
2. INCOME = Median household income.
3. FEMALE = Females, percent of total population.
4. HIGH SCHOOL = Percent of persons age 18+ that did not finish high school.
5. AGE = Percent of total population, age 60+.
6. CONGESTION = Roadway congestion, (annual person hours of delay).
7. COMMUTE = Average travel time to work (minutes).
8. OUTSIDE = Percent of workers age 16+ that work outside home county or state.
9. TRANSIT = Percent of workers age 16+ that use transit for work trip.
10. NAVY = 1 if major naval base is within metropolitan area; 0 otherwise.

With the exceptions of CONGESTION and NAVY, all data were collected from the DOT report. Data on CONGESTION were found in the 2000 Statistical Abstract of the United States from the U.S. Census Bureau. The variable represents annual person hours of delay (in 1997) in virtually each of the same metropolitan areas as the DOT report. The binary variable NAVY was compiled by the author, based on information from the U.S. Navy website on the location of its major naval bases. The inclusion of this variable may not seem logical intuitively, but its use was unexpected and will be discussed more closely in section VI, the results and interpretation of model I.

Since comprehensive data were not available on the specific number of telecommuters—with corresponding income or education levels, among other
variables—these data are used as proxies. And as will also be discussed later in both the model hypothesis and limitations sections of this paper, the benefits of using these data far outweigh their costs.

Although it would be preferable to have recent data on the number of telecommuters, using at-home workers instead should not yield terribly different results. Most of the theoretical reasons why people choose to work at home instead of in the office have not changed. Additionally, as noted by numerous previous studies, the vast majority of telecommuters participate at home rather than satellite offices or telecenters. As a result, these data should reflect very similar characteristics and amounts compared with raw telecommuting data. And although the data are slightly older than initially desired, the theoretical model would not change within five to seven years; no evidence within the previous literature has suggested that the characteristics of telecommuters have changed over time. As discussed in the first section of this paper, telecommuting is not a new concept and has been slowly gaining popularity for years. These data, therefore, should be well suited for better understanding the economic motivations and causes of telecommuting because it closely mirrors the type of data desired, as it is more comprehensive and thorough than otherwise would be possible with information from the various surveys and pilot programs.

In order to examine the economic consequences of telecommuting, data were used from a variety of sources. No clear method exists for determining the current or long-term impacts of telecommuting or the myriad implications of its increasing popularity, including any effects from its recent trends. As a result, the opportunity to analyze the possible implications was unique, as the process could be performed at my discretion.
Therefore, I, chose to inspect the possible consequences of telecommuting using various methods to ensure, as best as possible, that a biased or narrow focus was not applied.

To look at the possible air quality effects, vehicle emissions data were found from the Bureau of Transportation Statistics, which includes emissions figures on hydrocarbons, carbon monoxide, and nitrogen oxide. The transportation implications and other consequences of telecommuting will be examined using the limited data from several of the studies mentioned previously, such as Mokhtarian (1998), Pratt (1999), and DOT (1992). For example, information on the current number of telecommuters, typical miles driven, and average number of days telecommuting can be used together to infer possible implications from telecommuting. Additionally, data on average commute distances were found from the Bureau of Transportation Statistics. To understand the overall effects of telecommuting, the specific data on telecommuting were compared to several national data sets. For example, national vehicle miles traveled were collected from the Nationwide Personal Transportation Survey of the Federal Highway Administration (1995), and national emissions rates were found from the Environmental Protection Agency's National Air Quality and Emissions Trends Report, 1995. The specific details on how these data are used together and their respective results will be discussed in section VIII, the results and interpretation to the consequences of telecommuting.

V. Model I Hypothesis: Economic Causes of Telecommuting

As discussed previously, teleworkers can be found in various occupations, industries, and geographic locations. However, as discussed by Davis and Polonko (2001), among others, several characteristics may be helpful in determining what factors
lead people to telecommute. While the data set from the DOT report do not include statistics such as the number of at-home workers by occupation or industry, the data provide information on a variety of other variables that may be significant determinants of the causes of telecommuting. This model uses a number of variables from the DOT report to determine which geographic areas have the most telecommuters. That is, this section will first discuss the likely variables to be included in a model that examines the factors that cause people to telecommute, and then theorize the likely functional form to be used.

As discussed by Davis and Polonko (2001), teleworkers tend to have higher education and income levels than non-telecommuters and are more often male. Pratt (1999) also found that telecommuters are usually well educated, and the Census Bureau (1998) revealed that many at-home workers earn considerably more than non-telecommuters—although the report also noted that some may earn significantly less money than their commuting counterparts. As a result, income seems to have a positive correlation with telecommuting, although its strength as a predictor is unclear since lower-wage telecommuters may weaken its predictive ability. If the number of higher wage telecommuters prevails, INCOME should have a positive sign and be statistically significant. The relative strength of INCOME should be tested in the model.

Since Davis and Polonko (2001) discovered that telecommuters are more likely to be male, gender may also be a good indicator of telecommuting. Mokhtarian et al. (1996), however, noted that conventional wisdom suggests that telecommuting may be more attractive to women, as they often do a disproportional share of domestic responsibilities. She also found that women are more likely than men to cite family and
personal benefits as advantages of telecommuting. At the same time, Mokhtarian et al. (1996) also discovered that men are attracted to the possibility of telecommuting, as she illustrated that many men indicated a desire to try telework. Therefore, it is also unclear whether gender will be a good indicator of telecommuting. The expected sign of FEMALE should be negative according to Davis and Polonko (2001), although a positive sign would be possible, as discussed by Mokhtarian et al. (1996).

Since both Pratt (1999) and Davis and Polonko (2001) discovered that telecommuters have higher education levels than non-telecommuters, the inclusion of HIGH SCHOOL should be statistically significant and have a negative sign (HIGH SCHOOL represents the percentage of people that did not finish high school). Although not available, additional education measures, such the percentage of people that hold graduate degrees or that did not finish college, may also be good predictors. Since many telecommuters are managers and professionals, graduate degrees may be a better educational threshold; similarly, HIGH SCHOOL would neglect workers that completed high school but did not finish college. Despite these circumstances, the inclusion of HIGH SCHOOL into the model makes sense and may turn out to be a sufficient educational measure.

While the previous literature has not explicitly discussed the issue of age demographics, including the variable AGE may be sound based on the premise that telecommuters are often managers, professionals, and executives. While managers and professionals can be of any age, executives tend to be older, and telecommuters are also more likely to be experienced employees that have developed trust and a reputation from employers. Newer employees are less likely to telecommute. Older employees may also
be more tired of their daily commutes or have greater flexibility that allows them to telecommute because they have well established clients and work schedules. In many professional services firms, client contact and relationship management are often handled by seasoned executives, meaning they are freer to work by alternative means on those days that they do not meet with clients. However, since AGE represents the percentage of workers that are greater than 60 years of age, its predictive power may not be great because the age level is too high. Many managers may be in their 40s or 50s, and will, therefore, not be represented by the variable AGE. In sum, its ultimate effect in the model is unclear, but its inclusion is worth testing and has some evidence to support it.

Surprisingly, the use of CONGESTION as an indicator of telecommuting potential has not been as widely discussed in the literature as would have been expected. Some researchers, however, have suggested that people enjoy telecommuting because they benefit from reduced stress that normally occurs while commuting. Presumably, traffic congestion would be a considerable cause of stress, implying that CONGESTION could be a significant variable in the model. At the same time, researchers have not suggested that more people telecommute in areas that suffer from greater traffic congestion. The majority of discussions involving congestion have focused on the fact that many policymakers and public planners hope that telecommuting has the potential to alleviate traffic concerns in various areas of the country. Researchers have tried to illustrate that telecommuting can be an effective tool for fighting congestion and have not discussed in detail whether congestion has contributed to the rise of telecommuting.

Although the overwhelming majority of Americans travel to work by automobile (over 90%), CONGESTION measures annual person hours of delay only by automobile,
and would, therefore, ignore those workers that travel to work by public transit or other means (U.S. Census, Statistical Abstract of the United States: 2000). Some workers may decide to telecommute from stress created by the use of public transportation or other modes of travel. Most researchers have stressed the variety of personal reasons that workers decide to telecommute. The use of CONGESTION is, therefore, not expected to play a significant role in the model, although a positive relationship with telecommuting would not be unlikely and could be a natural outcome reflecting the fact that many people telecommute to avoid heavy traffic congestion.

Similar to CONGESTION, researchers have discussed various aspects related to commuting time without explicitly stating that telecommuters tend to have longer commute times than non-telecommuters. Mokhtarian (1997) revealed that teleworkers on average live twice as far from work as others. This implies that telecommuters may have longer commute times to work; however, longer distances do not necessarily translate into longer commuting times. A greater travel distance in a less populated area can be covered in a similar amount of time compared to one in a more densely populated area with more congestion. Since corresponding data on commuting distance are not available, it is difficult to know whether longer commute times are a result exclusively of greater commuting distances.

Additionally, the variable COMMUTE consists of average commuting times by any means of travel, not just by automobile. As a result, it may not properly reflect Mokhtarian's (1997) suggestion that telecommuters often live farther away from their places of work than non-telecommuters because longer commute times could be a result of slow public transportation or areas with greater roadway congestion. Nevertheless, the
use of COMMUTE should be tested in the model because longer commute times may lead workers to telecommute, based on the notions that many workers are eager to telecommute for personal reasons such as reduced stress, and a long commute time can certainly add to worker stress.

Since it measures the percentage of workers that work outside of their home county or state, OUTSIDE may be a similar predictor of telecommuting than COMMUTE. With the exception of those workers that live close to county or state lines, OUTSIDE could be a better measure of people willing to work greater distances from their homes. Using OUTSIDE could also be a solution to the drawbacks of COMMUTE; namely, the fact that longer commute times can be a function of traffic congestion as opposed to longer travel distances. As a result, OUTSIDE may be able to better reflect the idea that telecommuters have begun to live farther away from their places of work than non-telecommuters, as suggested by Mokhtarian (1997). OUTSIDE could, therefore, be a useful variable and would be expected to have a positive sign.

While the variable TRANSIT may represent those workers that have stressful commutes with public transportation, little or no evidence in the previous literature suggests that the use of public transportation should be a significant cause of telecommuting. However, TRANSIT should be tested in the model based on two competing ideas. First, more people may telecommute in geographic areas that rely on more public transit because of a preference among some people to avoid the additional hassles of public transportation. And second, some people may choose to telecommute in areas with less public transit because they can avoid the stress of driving themselves through rush-hour traffic each day. While the literature does not suggest that TRANSIT
should be a factor in telecommuting, these other intuitive theories suggest that it is worth testing.

While the selection of some variables seems clearer than others, the proper functional form to model telecommuting appears more straightforward. As there is no specific limit, or saturation level to the number of potential telecommuters, a linear functional form seems plausible. The relationship between AT-HOME and the explanatory variables also seems linear. For example, as COMMUTE or CONGESTION rises, the number of telecommuters, or AT-HOME, is expected to do the same. Similarly, AT-HOME is expected to fall given a greater HIGH SCHOOL percentage, since telecommuters are usually better educated than workers that do not participate. The explanatory variables, therefore, seem to have rather simple linear relationships with AT-HOME, whether positive or negative.

Additionally, a hyperbolic, or reciprocal, functional form implies a minimum threshold level. No minimum level of COMMUTE or CONGESTION is required for the number of telecommuters to rise. As discussed previously, even with short commute times and little traffic congestion, some workers may prefer to telecommute for a variety of other personal reasons. A hyperbolic functional form, therefore, does not seem like a good fit for this model.

Other functional forms are available; however, little theory or evidence suggests that one of these would be preferable to one that is linear. While the number of telecommuters may eventually increase at a lesser rate in response to increases in variables such as COMMUTE or CONGESTION, the evidence is not strong enough to suggest that a semi-logarithmic form should be used instead. The previous literature has
not revealed that the responsiveness of the dependent variable, AT-HOME, to the independent variables should change much over time. Additionally, a linear functional form is the default form and is usually the best place to begin; little or no existing evidence recommends that another functional form would be better suited in its place.

In sum, while the strength of some explanatory variables remains unclear, the likely functional form seems well supported. The best indicators of telecommuting appear to be FEMALE, HIGH SCHOL, OUTSIDE, and INCOME, while the contributions of AGE, CONGESTION, and COMMUTE are less clear. The use of TRANSIT is not expected to play a significant role in the model because its inclusion is not well supported in the literature. The introduction of the variable NAVY was discovered by examining residuals and will be explained in the following section. Additionally, a linear functional form is most likely to be the best choice, and its selection is maintained by both theory and a lack of evidence disproving its use.

VI. Results and Interpretation I: Economic Causes of Telecommuting

As the theory previously discussed suggested, modeling the economic causes of telecommuting yielded some expected and surprising results. This section will serve to explain the results of the most relevant regressions of the model in the context of the topics presented thus far. The detailed results of all relevant equations along with the univariate statistics can be found in the appendix at the end of this paper.

Based on the evidence discussed in the literature review, along with the theory presented in the previous section, a first regression was run using the seven variables INCOME, FEMALE, HIGH SCHOOL, AGE, CONGESTION, COMMUTE, and
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OUTSIDE, as they are expected to be the most likely variables to cause telecommuting.

Surprisingly, while most variables were statistically significant, CONGESTION and COMMUTE were not. Neither CONGESTION nor COMMUTE were even close to having statistical significance, and COMMUTE had a negative sign, which was certainly not to be expected. After further inspection of these results, including additional tests, it became clearer that the model suffers from slight multicollinearity. As discussed in the previous section, COMMUTE and CONGESTION could potentially reflect similar conditions, and it appears as though that may be the case here. The correlation coefficient between these two variables was also higher than desired, given as 0.678.

A subsequent step involved running the same model, except including either CONGESTION or COMMUTE, and not both variables together. As just discovered, neither CONGESTION nor COMMUTE were statistically significant in response to various tests, while most other variables contained the desired or near-desired results. It, therefore, became clear that neither commuting time nor roadway congestion is a good indicator of telecommuting in this model. While the previous literature has not specifically discussed these variables as likely determinants, their lack of any statistical significance was still surprising given the indirect evidence which suggested that they may be good predictors. For example, Mokhtarian (1997) suggested that telecommuters often live greater distances from their places of work than non-telecommuters, implying that their commuting time may be longer. Similarly, traveling a longer commute would be more bearable if it was not performed every day, as could be done through telecommuting. This indirect evidence suggests that COMMUTE would be a good indicator of telecommuting. This does not appear to be the case here, and some possible
explanations for this outcome will be discussed in the extensions and limitations section of this paper.

In light of these circumstances, another regression combination was performed using the remaining five variables: INCOME, FEMALE, HIGH SCHOOL, AGE, and OUTSIDE. The results of this model were vastly improved and are mostly consistent with expectations. As expected, the estimated coefficients of the variables OUTSIDE and AGE are positive, given the values 0.016 and 0.041, respectively. The inclusion of the variable OUTSIDE is statistically significant at the one-percent confidence level while AGE is significant at the ten-percent level. As a result, it seems that OUTSIDE, or working outside one's home county or state, is a good predictor of telecommuting. That is, people are more likely to telecommute if they have to work in a different county or state than their home. This result is not surprising and may be a reflection of the fact that OUTSIDE is a better indicator of commuting distance than COMMUTE. And as previously discussed, Mokhtarian (1997) suggested that commuting distance may be a good indicator of telecommuting.

The fact that AGE has a positive sign and is statistically significant reveals that workers that are sixty years of age and above are more likely to telecommute. While managers and professionals are of all ages, most executives are usually older. This outcome may reflect that executives are more likely to telecommute, which is consistent with the theory and evidence presented above. Additionally, it could imply that older workers telecommute because they are more tired of commuting or have reached a stage in their careers that afford them more flexibility with their employers. Testing additional
age demographics would have been preferable; however, this variable was the best available, and its outcome is also supported by theory and evidence.

Also as expected, the estimated coefficients of both FEMALE and HIGH SCHOOL have negative signs. Respectively, the coefficients are $-0.546$ and $-0.052$ and both variables are statistically significant at the one-percent confidence level. This implies that both females and workers that did not finish high school are less likely to telecommute. Additionally, the relative effect of FEMALE on AT-HOME is greater than HIGH SCHOOL. That is, a one-unit increase in the percentage of females will result in fewer telecommuters than a one-unit rise in the percentage of workers that did not finish high school. These findings are consistent with previous research. Davis and Polonko (2001) suggested that telecommuters are typically male and well educated; likewise, Pratt (1999) also noted that teleworkers usually maintain higher education levels than their commuting counterparts. Statistical significance and negative signs have met these expectations.

The results of the variable INCOME, however, were not as expected. The estimated coefficient of INCOME has a negative sign with the value $-0.0003$, and is statistically significant at the ten-percent level. Both Davis and Polonko (2001) and the Census Bureau (1998) revealed that many telecommuters tend to have higher income levels than non-telecommuters, which does not coincide with the results from this model. The Census Bureau (1998) also noted that some telecommuters earn considerably less money than regular commuters. As a result, it is possible that the effects of the lower-income earners outweigh those of the higher income earners in this model, which would, therefore, yield consistent results. Even though it would not fully explain this outcome, a
binary variable of the locations with the lowest income levels was not statistically significant. And as will be discussed further in the extensions and limitations section, two other reasons can help explain this outcome: the existence of multicollinearity and the use of at-home workers as an approximation for telecommuters. Both topics will be addressed in section IX.

After reviewing these results, it became clear that the predictive power of FEMALE relative to other variables is very large. While some evidence did suggest that telecommuters are more often male, its relative strength was unexpected. Examining these regressions further disclosed that several outliers were consistently apparent. Norfolk, Virginia and Honolulu, Hawaii were two such examples. A well-known military presence is evident in both locations, which led to the idea that the presence of a naval base may indicate areas with a lower percentage of females and more telecommuters. A binary variable, NAVY, was created specifying the geographic locations with well-established naval bases, and its inclusion into the model is statistically significant at the one-percent confidence level, with an estimated coefficient of 0.576.

This very interesting result implies that more people telecommute in areas with large naval bases. Two possible reasons may help explain this outcome: gender and technology. If males are more likely to telecommute, as demonstrated above, geographic areas with large naval bases may have a greater percentage of men in the region. In addition, although many military personnel may not be able to telecommute, the surrounding area may contain a higher percentage of technology-oriented workers, such as consultants and engineers working with the military or other organizations. These
workers would be more likely to telecommute given their industry occupations and technological knowledge, as well as the fact that some civilians may not have consistent access to naval facilities; the latter condition could force those workers to telecommute. These two reasons may help explain why NAVY is a relatively strong indicator of telecommuting. Similarly, these areas with fewer females and more telecommuters would also help clarify why FEMALE plays a dominant role in this model.

While the results of this model are largely consistent with both theory and previous evidence, the use of INCOME and its subsequent results are not as well supported. While the existence of multicollinearity and the approximation of telecommuters with at-home workers may help explain its surprising outcome, the same model works well without the inclusion of INCOME. Therefore, a final regression with the variables FEMALE, HIGH SCHOOL, AGE, OUTSIDE, and NAVY appears to be the best fit for modeling the economic causes of telecommuting. The final model can be expressed as follows:

$$AT-HOME = \beta_0 + \beta_1FEMALE + \beta_2HIGH\ SCHOOL + \beta_3AGE + \beta_4OUTSIDE + \beta_5NAVY + \epsilon$$

Each variable maintains its expected sign and the overall outcome is consistent with the theory and evidence presented above. While the relative strengths of AGE and OUTSIDE are slightly less without the inclusion of INCOME, this outcome can be explained in part due to the existence of multicollinearity and the slight instability among these three variables. Despite this drawback, this model is well-suited for explaining the variables that affect telecommuting.

In sum, the estimated coefficients of FEMALE and HIGH SCHOOL are negative, and the variables are statistically significant at the one-percent level. This implies that
male workers with higher education levels are more likely to telecommute than others. Additionally, OUTSIDE and AGE are close to but not statistically significant at the ten-percent level; the inclusion of NAVY is also statistically significant and is an interesting inclusion to the model, as discussed above. These latter results imply that older workers and workers that live in a different county or state than their worksites are more likely to telecommute. These results are largely consistent with both theory and the previous evidence and suggest that individual, or personal variables, are the most important factors in determining whether people telecommute. These results, however, are not without limitation, and section IX will discuss these issues in more detail.

VII. Model II Hypothesis: Economic Consequences of Telecommuting

While there is considerable evidence from which to begin theorizing the likely determinants of the economic causes of telecommuting, examining the economic consequences has much less direction. Much of the recent excitement about telecommuting centers around the notion that many policymakers and public planners hope that telecommuting will be an effective tool to help solve a growing number of social problems, from roadway congestion to cleaner air. While Pratt (1999) and the DOT (1992) have indicated that telecommuting may already be addressing some of these concerns, Mokhtarian (1997) and Gordon (1999), among others, have noted that the reality of whether telecommuting can realize its full potential is still unclear. Therefore, it is expected that the economic consequences of telecommuting may vary according to different methods of examination. Choosing the right estimates for the number of telecommuters, as well as other statistics, is important because such decisions can greatly
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influence the overall consequences of telecommuting. As will be explained further in the following section, this model focuses on the impact of telecommuting on the number of vehicle miles traveled by workers. This section will present the theory and hypotheses behind the potential consequences of telecommuting, allowing the next section to demonstrate more clearly the possible outcomes from increased telecommuting.

As discussed in the data sources and description section, the current estimates on the number of telecommuters vary widely, and the causes of these discrepancies have been two-fold. First, most telecommuters participate on an individual or informal basis rather than full time, and telecommuting has recently evolved to include a wider variety of mobile work, such as working on the road, in airports, and Internet cafés. These characteristics make it difficult for researchers to accurately estimate the number of telecommuters in the United States. And second, some researchers define telecommuters differently from others, as discussed previously, leading some researchers to predict different numbers of telecommuters among one another. Examining the economic consequences of telecommuting is, therefore, largely dependent on the estimates chosen for analysis.

According to Jala International, Inc., a consulting firm founded by Jack Nilles, one of the pioneers in telework-related initiatives, the number of telecommuters will rise steadily throughout the next few years. A graph of their current forecast on the number of telecommuters is shown below:
Within the next several years, significant portions of the U.S. labor force will be telecommuting, implying that the long-term effects of telecommuting could be large. Gil Gordon, another leader in the field of telework, suggests that the typical growth in telecommuting has been around 10-15% annually (http://www.gilgordon.com). He also notes, however, that predicting the number of telecommuters will be difficult for timelines greater than five years, as telework continues to expand its scope and the workforce continues its current trend of broader mobility.

In her comprehensive survey of telework, Pratt (1999) discovered that telecommuters reduce their overall vehicle miles traveled by 1,800 miles annually per teleworker. With approximately 28 million telecommuters in the U.S. today (Davis & Polonko, 2001), the overall reduction in vehicle miles traveled annually could be considerable. Such reductions would translate into fewer automobile emissions and reduced energy consumption. Automobile emissions are a significant source of greenhouse gases, and a large reduction in current emissions as a result of telecommuting
could have great potential benefits for the environment. Additionally, reduced energy consumption based on fewer vehicle miles traveled could potentially reduce the United States' dependence on the importation of foreign oil.

Policymakers, along with state and local municipalities, hope that large reductions in vehicles miles traveled such as these would help alleviate their growing concerns of roadway and transportation demand in addition to traffic congestion. Telecommuting can potentially reduce the overall number of automobiles on the roads as well as spread the demand for highway use beyond peak times. For example, some workers could telecommute for several hours in the morning and drive to work later in the day, avoiding rush-hour traffic. This theory implies that telecommuting could lead to large potential benefits.

At the same time, however, different theory suggests that the potential benefits of telecommuting may no be as great. As noted in the literature review, Mokhtarian (1997 and 1998) revealed that some telecommuters may actually take more trips in their cars than previously, whether to avoid cabin fever or to do additional errands. Many typical car trips, such as grocery shopping and picking up children from school, that could normally be done en route to or from work would require specific trips for workers while telecommuting. For example, Davis and Polonko (2001) found that teleworkers typically drive 5.7 to 18.6 miles per work day on errands and other related tasks. This implies that the overall reduction in vehicle miles traveled as a result of telecommuting would not be nearly as great as discussed above. According to the Nationwide Personal Transportation Survey conducted by the Federal Highway Administration (FHWA), workers' average commute trip distances in 1995 were 23.26 miles roundtrip. If teleworkers run the
amount of errands as suggested by Davis and Polonko (2001), this distance is almost the same as that of many workers' regular commute. The overall benefits from telecommuting would be reduced considerably.

As also noted by Mokhtarian (1998), overall reductions in the number of vehicle miles traveled may not be as great as initially suggested. Some telecommuters may begin to live farther away from their places of work, since longer commuting distances are more bearable if work trips are conducted on fewer occasions. Additionally, if telecommuting is successful in alleviating some traffic congestion, latent travel demand may partially offset some of these reductions.

To conclude, the overall economic consequences of telecommuting are unclear and greatly depend on the statistics and parameters used for examination. It is, therefore, expected that the results of this model would vary depending on the method used. The following section will analyze the consequences of telecommuting by focusing on vehicle miles traveled and using several methods to ascertain the potential effects of telecommuting.

VIII. Results and Interpretation II: Economic Consequences of Telecommuting

While the methods for examining the economic causes of telecommuting are based on both theory and prior evidence, the techniques for inspecting the economic consequences are less clear. As a result, this section will examine several methods for determining the effects of telecommuting so that possible biases are reduced. Since telecommuting has the potential to impact numerous areas of the economy or public policy, this study will focus primarily on the effects of vehicle miles traveled (VMT).
Data and statistics on information related to vehicular travel and automobile emissions are comprehensive and widely available. Combining this information with the limited, but important, data from a variety of studies discussed in this paper presents a detailed illustration of the potential impacts of an increase in telecommuting.

Given some of the information thus far discussed in this paper, it seems that telecommuting has the potential to reduce overall VMT considerably within a best case scenario. In turn, these reductions could lead to several benefits, such as fewer automobile emissions and less energy consumption. According to Pratt (1999), the average telecommuter reduces his or her overall vehicle miles traveled by 1,800 miles annually. Within her study, she defined telecommuters as those workers that participate at least once a month. Davis and Polonko (2001) suggested that there are approximately 28 million telecommuters today, using the same criterion for defining telecommuters as Pratt (1999). This implies that telecommuting could potentially reduce overall VMT by approximately 50.4 billion miles in a given year. In the Nationwide Personal Transportation Survey, the Federal Highway Administration (FHWA) revealed that there were over 642 billion vehicle miles traveled in 1995 on overall journey-to-work trips. At the current number of teleworkers, telecommuting could reduce the overall number of vehicle miles traveled by 7.85% annually. If the popularity of telecommuting continues to rise and the number of workers participating grows at the rates suggested by both Gordon and Jala International, Inc., the reduction in VMT would continue to increase each year as a greater percentage of the overall level. These reductions in automobile travel could have a number of different effects, as will be described below.
Automobile use is also a serious concern because of its production of greenhouse gas emissions, in addition to causing problems such as roadway congestion. Air pollution is now a growing concern, and greenhouse gases are a significant cause of climate change. As a result, many government agencies are interested in learning whether automobile emissions can be reduced by telecommuting. Given the 50.4 billion vehicle miles traveled that could be reduced from telework each year, the reduction in automobile emissions can be considerable. Using the emissions data from the Bureau of Transportation Statistics, as discussed in the data sources section, an average emissions per mile can be calculated based on the emissions for light-duty vehicles and light-duty trucks. An analysis of the consequences of telecommuting, can therefore, be conducted for the following pollutants: hydrocarbons (HC), carbon monoxide (CO), and nitrogen oxide (NO$_x$). A table summarizing the potential emissions reductions from telecommuting is shown below:

**TABLE 2. ANNUAL EMISSIONS REDUCTIONS**

<table>
<thead>
<tr>
<th>Pollutant</th>
<th>Emissions Saved (000,000 of grams)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hydrocarbons (HC)</td>
<td>126,504</td>
</tr>
<tr>
<td>Carbon Monoxide (CO)</td>
<td>1,115,900</td>
</tr>
<tr>
<td>Nitrogen Oxide (NO$_x$)</td>
<td>80,136</td>
</tr>
</tbody>
</table>

That is, given 28 million telecommuters in the United States (and each teleworker reduces VMT by 1,800 miles annually), telecommuting could reduce emissions of these three pollutants to a great degree. Based on the Environmental Protection Agency's
(EPA) National Air Quality and Emissions Trends Report, 1995, the total national emissions for light-duty gas vehicles and trucks are available for both carbon monoxide and nitrogen oxide. If telecommuting can reduce vehicle emissions by the levels demonstrated above, the consequences of telecommuting can be shown more clearly. That is, one can better understand the overall effects of telecommuting by illustrating the true magnitude of such emissions reductions. The following table represents the percentage of national emissions (the total for light-duty gas vehicles and light-duty gas trucks) that can be reduced by telecommuting at the levels presented above.

<table>
<thead>
<tr>
<th>Pollutant</th>
<th>% of total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Carbon Monoxide (CO)</td>
<td>2.83</td>
</tr>
<tr>
<td>Nitrogen Oxide (NOₓ)</td>
<td>1.96</td>
</tr>
</tbody>
</table>

While these percentages may be relatively small, they would grow considerably if the number of telecommuters continues to rise at the rate that some researchers have suggested. As illustrated in the previous section, Gil Gordon suggested that the number of teleworkers has grown at roughly 10-15% annually, while Jala International, Inc. predicts there will be over 45 million telecommuters within the next ten to fifteen years (http://www.gilgordon.com; http://www.jala.com). Therefore, not only can telecommuting help reduce traffic congestion, but these emissions reductions produce societal benefits in the forms of cleaner air and reduced smog.
In addition to reducing the amount of automobile emissions, a reduction in the number of vehicle miles traveled could have other implications as well. According to the Bureau of Transportation Statistics, the average motor vehicle miles per gallon (of passenger cars and light trucks) is 19.75 miles per gallon. At the telecommuting levels illustrated earlier in this section, telecommuting can reduce overall vehicle miles traveled by 50.4 billions miles annually. This translates into roughly 2.5 billion gallons of gasoline per year that can be saved by telecommuting. A petroleum industry website (http://www.petroleum.org) reveals that one barrel of crude oil makes approximately 19.5 gallons of gasoline. Thus, telecommuting can reduce the national intake of crude oil by over 130 million barrels per year. The Energy Information Administration Monthly Review states that the United States imported, on average, 9.1 million barrels of crude oil per day in 2001, or over 3.3 billion barrels annually. Telecommuting could, therefore, reduce the level of imported crude oil by 3.92% annually. While this is currently a relatively small number, the percentage could grow rapidly if the popularity of telework continues as previously described.

In trying to understand how telecommuting can reduce vehicle miles traveled, it became clear that such large reductions in automobile emissions are not necessarily assured. There are several techniques for measuring the amount of vehicle miles saved from telecommuting, and different estimates greatly affect the results that express the consequences of telecommuting. Using data from various sources, a similar estimate to that given by Pratt (1999) is revealed for the reduction in VMT. For example, according to the FHWA (1995), the average roundtrip commute to work in the U.S. is 23.26 miles. And as noted by several sources discussed in this paper, the average telecommuter
participates one to two times each week, or 78 times each year. This implies that each
teleworker reduces work-related VMT by 1,814.28 miles each year. This number is
virtually identical to that found by Pratt (1999): she estimated 1,800. However, as
discovered by Davis and Polonko (2001), teleworkers average roughly 12.15 miles per
day on errands or other related tasks. As a result, the reduction in VMT would be only
866.58 miles per year rather than 1,814.28. Potential emissions reductions from
telecommuting would, therefore, be considerably less. A table summarizing the potential
emissions reductions follows below:

<table>
<thead>
<tr>
<th>Pollutant</th>
<th>Emissions Saved (000,000 of grams)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hydrocarbons (HC)</td>
<td>60,893</td>
</tr>
<tr>
<td>Carbon Monoxide (CO)</td>
<td>537,116</td>
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<tr>
<td>Nitrogen Oxide (NOx)</td>
<td>38,573</td>
</tr>
</tbody>
</table>

Although these reductions are still considerable, they are less than half of those predicted
above. This example demonstrates how the realistic effects of telecommuting are
difficult to quantify and depend greatly upon the data sources chosen. Just as the
magnitude of these emissions reductions is considerably less when considering worker
errands, so too is the magnitude of the effects related to national emissions levels and
crude oil. Whether addressing traffic congestion, air quality, or energy consumption, the
impacts of telecommuting are largely derived from vehicle miles traveled. As a result,
when examining the consequences of telecommuting, one must be aware of the fact that a
variety of outcomes are possible.
Although these estimates for the reduction in VMT per teleworker are nearly identical (1,814.28 compared to 1,800), my estimate falls to 866.58 miles annually once teleworker errands are considered. Pratt (1999), however, did consider the possibility that teleworkers often conduct errands while working from home—making the estimates far less similar. One possible explanation for the discrepancy is the fact that she discovered that teleworkers typically commute 36 miles roundtrip from their home to their places of work. According to the FHWA (1995), the average commuting distance is 23.26 miles roundtrip, a distance that is considerably shorter. If most teleworkers do, in fact, have longer commuting distances than non-teleworkers, the overall reduction in VMT would be greater than my estimate of 866.58 miles annually, as that estimate is derived from the national average commuting distance. These larger reductions, however, would only be temporary. As the number of telecommuters continues to increase, the average commuting distances among teleworkers would converge to the national average. And as mentioned previously, it does not appear that teleworkers relocate farther away from their places of work once they begin telecommuting.

While telecommuting can conceivably reduce vehicle miles traveled to a large degree, it is uncertain whether this potential is a reality. By telecommuting, workers can forego their regular commute (reducing VMT); however, these same workers will also drive on average an extra 12.15 miles per day on errands. In addition, if telecommuting provides workers with more free time, some may choose to take additional trips in the car. Likewise, telecommuting may allow the spouse or family member of a teleworker to make automobile trips because of the availability of an extra car. And as discussed earlier, latent travel demand is a serious concern if telecommuting is, in fact, successful.
in reducing overall vehicle miles traveled on roads and highways. As a result, the true economic consequences of telecommuting are difficult to determine, as they depend on a number of extraneous factors. Even in a worse case scenario, however, it seems that telecommuting reduces vehicle miles traveled, and such reductions yield a wide variety of benefits—such as cleaner air, eased congestion, and reduced energy consumption.

IX. Further Discussion: Extensions and Limitations

While the models and theories presented yielded outcomes largely consistent with expectations, these results are not without limitation. Several issues concerning both models require further discussion. As noted in the data sources and description section, the DOT data set consists of at-home workers rather than telecommuters. Although the evidence revealed that a model using at-home workers should not yield results considerably different than one using telecommuters, the use of AT-HOME is not a perfect approximation for telecommuting. Recent trends in telecommuting have led workers to telecommute in a variety of locations rather than the home. The variable AT-HOME would focus exclusively on home-based telecommuters and would ignore those telecommuters that participate in satellite offices, telecenters, or on the road. This fact may help explain why INCOME had a negative sign. While its unexpected negative sign could be a consequence of multicollinearity, it could also be a reflection of the fact that some home-based workers earn less money than traditional ones, as noted by the Census Bureau (1998). While both Pratt (1999) and Davis and Polonko (2001) revealed that teleworkers generally earn higher incomes, the percentage of home-based workers that
earn considerably less money could have outweighed the effects of the higher wage earners, leading to a negative sign.

In addition to using data on actual telecommuters, the first model could have been improved with data on additional variables. It is well documented in the previous literature that many teleworkers tend to be managers or professionals or in the services industry. Industry or occupational data would greatly improve the model and allow for the testing of additional theories. However, reliable and comprehensive data of this kind are not widely available. For the purposes of this study, the data set from the DOT is preferable because of its high quality and comprehensive nature. If additional variables were available, their inclusion into the model could greatly improve these results.

As discussed in previous sections, estimating an accurate number of telecommuters in the United States is difficult because the majority of teleworkers participate on an individual or informal basis. Similarly, counting the number of teleworkers that work on the road or in Internet cafés is also difficult. Choosing an accurate estimate for the number of telecommuters is very important when examining the economic consequences of telecommuting, as the effects of roadway congestion, vehicle miles traveled, and automobile emissions are dependent on the number of actual telecommuters. As a result, it is important to note that modeling the consequences of telecommuting can yield very different results when using different data sources. The model illustrated how the effects of telecommuting can quickly change, and it would be important for policymakers or public planners to acknowledge that the impacts of telecommuting may not always be consistent with a best case scenario.
While this study focused primarily on the effects of telecommuting on vehicle miles traveled, a number of other analyses could be performed. As noted earlier, currently little empirical or economic analysis has been conducted on the effects of telework, and this study could extend to other areas such as capital expenditures, worker productivity, and transportation demand. Examining the effects of telecommuting on transportation, such as highway use or travel demand, is a natural transition to this study but outside its scope. Understanding these impacts would require extensive survey analysis and data collection that is simply not possible within the scope of this study and is better suited for local or state municipalities.

When examining the consequences of telecommuting, this paper focused on the reduction of vehicle miles traveled (and its extensions) within a given year rather than depicting the effects over time. As previously discussed, forecasting the number of telecommuters is difficult and time horizons greater than five years are not likely to be accurate. Furthermore, forecasting the future effects of telecommuting would also require future estimates on automobile emissions, overall vehicle miles traveled, and energy consumption. As a result, presenting the current effects is more accurate and it can be easily understood how the impacts could potentially increase if the popularity of telecommuting continues to grow.

X. Conclusion

Based on the literature and theory reviewed, along with the numerous data sources collected, this paper has examined both the economic causes and consequences of telecommuting. As discussed in the first sections of this paper, telecommuting is a
concept that is gaining popularity among workers and attracting the attention of policymakers and public planners. Telecommuting has the potential to produce numerous benefits—from eased traffic congestion to improved air quality. Many public administrators are interested in learning whether telecommuting can realize its potential and help address a number of their growing concerns. My interest in this study began with the unusual characteristics of telecommuting and continued with the examination of its causes and consequences, which are largely unstudied. The majority of the studies on telework focus on qualitative issues, such as quality of life, and few comprehensive empirical analyses are available. While this study focused primarily on a few specific areas of telecommuting, it provides an initial framework from which to begin viewing the origination and future direction of telework.

The majority of the results found within this study are consistent with previous evidence, but this paper also demonstrates that many of the long-term impacts of telecommuting are still uncertain. While both workers and employers have largely enjoyed the implementation of telecommuting, the societal impacts depend on a variety of extraneous factors, as previously discussed. It is important to note that researchers often disagree on the definition of telecommuting and the number of teleworkers, as the concept is still evolving despite its introduction several decades ago. As a result, understanding the true impacts of telecommuting vary depending on the data sources used and the theoretical assumptions made. This paper has presented the potential consequences from a variety of perspectives to demonstrate how the effects of telecommuting can differ from one method of analysis to the next.
Despite the fact that the overall impacts of telecommuting can vary widely, most researchers agree that telecommuting can produce overall net benefits for workers, employers, and society. The future direction of telecommuting may be unclear, but the potential of telecommuting continues to be great. While some workers are ready to set aside their business suits for pajamas, the vast majority are not yet ready to change their practices. While it is important to note that its economic consequences are uncertain in the present, telecommuting is a current practice worth promoting for those individuals and firms well-suited for its characteristics, and as its popularity continues, the long-term economic effects of telework may someday become clear.
XII. Appendix

<table>
<thead>
<tr>
<th>Variable</th>
<th>Number</th>
<th>Mean</th>
<th>Standard Deviation</th>
</tr>
</thead>
<tbody>
<tr>
<td>AT-HOME</td>
<td>59</td>
<td>2.353</td>
<td>0.754</td>
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<td>INCOME</td>
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<td>4.906</td>
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<td>(6.19)</td>
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<td>(1.83)</td>
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<td>-0.056***</td>
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<td>FEMALE</td>
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<td>N</td>
<td>59</td>
<td>59</td>
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XII. References


Mokhtarian, P. L. (1998). A synthetic approach to estimating the impacts of


