Effects of distance work on the activity-travel pattern

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1 Introduction

Distance work relaxes one major constraint of people's everyday life; the need to be at a specific working site during a specific time interval. Therefore, profound changes can be expected due to distance work, possibly in different ways for men and women. Since the the response depends on individual preferences and various restrictions, an observed gender difference would indicate that men and women want different things and/or have different possibilities.[1] In this paper we will make an attempt to assess the effect of distance work empirically.

Distance work has been suggested as a solution that combines the best of the modern world with the resource efficiency and comfort of a traditional lifestyle (Sturesson, 2000). The idea is that distance work combines the benefits of large distance interaction, decreasing environmental problems and quality of life. However, it is not controversial to claim that the distance work debate is biased towards opinions and hopes and suffers from a deficit of empirical content.[2] There is therefore a need for empirical assessments of the consequences of distance work in terms of changes in the geographical and temporal dimensions of people's lives. We will call this complex of activities and movements the *activity-travel pattern*. A point of departure for our

[1] This might in turn be a function of roles, agreements and power relations. The importance of each of these factors are however beyond the scope of this paper.

[2] Salomon (1998) and Mokhtarian and Salomon (2002) talk about an excess of "armchair studies"

analysis is that distance work does not merely affect parts of the activity-travel pattern with immediate connections to work, but potentially the whole activity-travel pattern. This hypothesis is derived from the activity-based theory, where the assumption of work being a structuring element in the way activities and traveling are organized is a cornerstone (see for instance Golob, 2001). We estimate the effects of distance work on various aspects of the activity-travel pattern; the distance traveled using different transport modes, the time devoted to transports, the timing of transports and the distance between the home and various activities. Estimations are done using econometric matching on data material from the Swedish travel survey, RES, a travel diary collected in the period 1999-2001.

A conclusion of the study is that the factors behind distance work are different for men and women. When it comes to aspects of the activity-travel pattern, we find no statistically significant effects for men. For women, distance work means that the average distance from home to child care and places for purchases are reduced. We have also computed how the activity-travel pattern differences between men and women change due to distance work. Two of these total gender effects are individually significant, end time of the last trip and the distance between home and child care. Tests performed on groups of total gender effects also show that, in general, the impact of distance work on the activity-travel pattern is different for men and women.

In the next section we define distance work and hypothesize about its potential to change the activity-travel pattern. Then we define several specific research issues and present our data material. We continue with a theoretical framework and a description of the econometric method. The paper closes with an empirical analysis and conclusions.

1.1 Distance work and the activity-travel pattern

A distance worker has an agreement with his or her employer, allowing the former to work at places other than the regular working site. Working from home is probably the most common, although distance working centers have also been tried. That distance work is institutionalized in an agreement means that occasional work from other places does not qualify as distance work. The concept is relevant only for individuals whose work does not involve regular movements. Thus, craftsmen, sales people etc., for whom being in "other places" is an intrinsic feature of the job, do not qualify as distance workers.

The definition of distance work is in many cases blurred by excessive references to technical aids, e.g. information and communication technology (ICT). This is reflected in the closely synonymous "tele work". Since distance work is not only a function of technical aids, this is not a proper denomination. This does not mean, however, that ICT is not important. A Swedish study shows that 77 percent of the distance workers use computers, 46 percent can connect their computers to the company network and 72 percent have mobile phones (SIKA, 2003). Improvements of ICT might extend the pool of work that is possible to perform "at a distance" (see for instance Denstadli and Julsrud, 2003). Also, ICT might improve the social situation for distance workers (Börjesson, 2003). A survey has shown that tasks that cannot be done at other places than the regular working site constitute the reason for not doing distance work for 85 percent of the survey population (Rapp and Rapp, 1999). A Dutch study concludes that about 25 percent of all jobs should be possible to perform as distance work (Hjorthol, 2001).

The relation between distance work and the activity-travel pattern has been discussed by numerous authors[3]. To understand the coming empirical analysis and its relation to other studies in this field, a simple taxonomy is useful. It is meaningful to separate the short and long run (SR and LR) effects from distance work. By SR effects we mean the impact on the activity-travel pattern of actually doing distance work on a specific day. In the long run we can expect the activity-travel pattern to change not only on distance working days, but on other days as well, as a result of changed habits where activities are moved to other times and places. The most profound instances are perhaps changes in job or living location. The long term effect is the sum of all changes in the activity-travel pattern made possible by distance work (Skåmedal, 2004).

1.2 Research issues

Hitherto we have talked about the activity-travel pattern, a term useful in general discussions but too abstract to be used in empirical analyses. In order to undertake empirical analysis we have to define aspects of the activity-travel

[3]Patricia Mohktarian is among the most frequently cited researchers in this field (see e.g. Mokhtarian et al., 1995; Mokhtarian, 1997; Mohktarian and Meenakshisundaram, 1999). In Sweden recent research has been done by Skåmedal (2004) and Börjesson (2003).

pattern that capture important dimensions of the problem, and are simple enough to be measurable. With respect to the environmental issues, it is clearly relevant to study the amount of transport (in some sense). From a more individual perspective, factors such as time spent on transports and the timing of activities are important aspects of the activity-travel pattern. Besides, it is of great interest to analyse the location of activities, relative to the housing location, to see if distance work leads to a more local lifestyle or if it is used to take advantage of work opportunities and other activities further away from home.

2 Data

The data used in this paper is the Swedish travel survey, RES, a cross section travel diary collected in 1999-2001.[4] Traveling, during one day (evenly distributed over Monday-Sunday), is recorded as main trips, part trips and travel elements. The definition of main trips is that they start and end at home, leisure house, work, school or temporary places of living, e.g. hotels. Part trips are defined as movements between places of activities and travel elements are consecutive trips without change of transport mode. Every main trip is composed of one or more part trips and every part trip can be composed of one or more travel elements (SIKA, 2001b). Consider for example a commute trip starting at home and ending at work, thus satisfying the definition of a main trip. If the commute trip is a continuous journey without additional stops for errands, only one part trip is performed during the course of the main trip. But if one stop is made for leaving children at child care, the main trip consists of two part trips, and so on.

We use a sub-sample consisting of individuals that are employed, either full or part time, or self-employed (i.e. run their own businesses). This sums up to 8,485 individuals.[5] The definition of a distance worker used in RES is a person who performs his or her work at places other than the main working site on a regular basis. As noted above, craftsmen, sales people and

[4]It has been pointed out that Stated preference studies tend to overestimate the effects of ICT since people are affected by speculative visions. Information about actual behaviour, i.e. revealed preference data like RES, will more likely give reliable results (Mokhtarian and Salomon, 2002).

[5]Totally, the data consist of 17,219 individuals. The response rate for the 12 quarters of the survey is in the interval 66-76 percent.

others whose natural mode of work is to be on the road, do not fall within the definition of a distance worker. Work performed during commute trips, tasks done after work, business trips or occasional work at home, e.g. while attending children, are not defined as distance work (SIKA, 2001a). In our sub sample we have 391 individuals who are distance workers and 7,820 that not do distance work.[6] As can be seen in table 1 this means that about 5 percent of the individuals in our sample are distance workers. We can also see that 10 percent are self-employed and that 17 percent are part-time workers. A little more than half of the individuals are men and the average age is about 43. 76 percent of the individuals are married and the average number of household members is 2.75. Most of the individuals, 91 percent, have a driving licence and the number of cars in their households is 1.3 on average. 64 percent live in their own houses. The education level is 2.10 on average. This means that an average Swedish worker has somewhat more than a high school education (the education level is an ordinal scale variable where 1=elementary school, 2=high school, 3=university degree, 4=graduate studies).

The second part of table 1 which is based on sector dummies describes in which sectors the individuals work. The most common is the manufacturing sector (19 %), followed by health care (18 %) and real estate (10 %). The fishing industry is the smallest sector in our data, but the zero mean is due to rounding error.

The individuals in our data perform 27,757 part trips in total (1,027 individuals do not perform any trips during the day). The start and end points of each part trip are geographically determined by their small area, SAMS[7], which has a $\{x, y\}$ coordinate in the official Swedish coordinate system.[8] The unit of these coordinates is metres, which facilitates computation of the distance between two points. We compute the distance between the individuals home and his/hers working place and other places where activities take place (i.e. where part trips end). A problem is that activities located in the same SAMS area as the house generate a zero distance. This is the most exact geographic information included in RES though.

[6]The distance work variable has 274 missing values.
[7]SAMS=Small Area Market Statistics (Statistics Sweden, www.scb.se).
[8]Rikets nät (www.lantmateriet.se).

Table 1: Descriptive statistics - socio economic variables

	Mean	Std. dev	Min	Max	Valid obs
Distance worker	0.05	0.21	0	1	8,211
Self employed	0.10	0.30	0	1	8,485
Part time	0.17	0.38	0	1	8,485
Male	0.53	0.50	0	1	8,485
Age	42.8	11.94	14	83	8,485
Income (1000 SEK†)	234	138	0	5,000	7,320
Married*	0.76	0.43	0	1	8,485
Household size	2.75	1.31	0	1	8,478
Drivers licence	0.91	0.28	0	1	8,485
Nr cars	1.30	0.81	0	1	8,485
House	0.64	0.48	0	1	8,485
Education level	2.10	0.72	1	4	8,413
Construction	0.05	0.22	0	1	8,485
Electric/gas	0.01	0.09	0	1	8,485
Real estate	0.10	0.30	0	1	8,485
Finance	0.02	0.13	0	1	8,485
Fishing	0.00	0.02	0	1	8,485
Hotel	0.02	0.14	0	1	8,485
Health care	0.18	0.38	0	1	8,485
Farming	0.02	0.14	0	1	8,485
Public admin	0.06	0.23	0	1	8,485
Retail	0.11	0.31	0	1	8,485
Publ pers serv	0.04	0.20	0	1	8,485
Manufacturing	0.19	0.39	0	1	8,485
Transport	0.06	0.23	0	1	8,485
Education	0.07	0.26	0	1	8,485

†Swedish currency unit. 1 Euro = 9.4 SEK (070404)

*People that are either married or living under conditions similar to marriage.

Table 2: Descriptive statistics - activity travel indicators

	Men					Women				
	# obs	Mean	Std	Min	Max	# obs	Mean	Std	Min	Max
Main trips per day	4,409	2.06	1.45	0	16	4,076	1.95	1.32	0	13
Part trips per day	4,409	3.31	2.58	0	21	4,076	3.22	2.47	0	24
Traveled distance (km/day)										
Total	4,409	61.28	170.80	0	6,260	4,076	43.20	149.51	0	5,320
Walk, bike	4,409	1.27	3.55	0	52	4,076	1.54	3.33	0	48
Local public	4,409	2.36	11.60	0	168.2	4,076	3.24	14.41	0	376.5
Car	4,409	44.41	83.48	0	961	4,076	28.89	57.90	0	1092
Train	4,409	2.04	27.59	0	620.15	4,076	1.87	23.22	0	550.3
Other	4,409	11.19	149.55	0	6,260	4,076	7.63	137.82	0	5320
Temporal information (min)										
Total travel time	4,409	79.49	97.96	0	1,080	4,076	68.94	77.26	0	930
Start time first trip	3,786	549.52	199.27	60	1,410	3,516	584.26	192.57	0	1,380
End time last trip	3,786	1,027.14	267.49	60	1,440	3,516	1,035.01	243.55	60	1,440
Average distance from home (km)										
Total	3,680	14.30	54.19	0	957.72	3,431	10.57	44.31	0	933.04
Work	2,191	7.78	34.66	0	957.72	1,929	4.57	14.47	0	382.95
Purchases	851	13.24	55.10	0	743.46	1,041	9.05	36.61	0	503.31
Child care	80	1.12	2.26	0	17.09	197	1.94	4.32	0	37.06
Leisure	1,574	13.45	52.42	0	582.11	1,567	14.86	57.13	0	933.04
Drive another person	418	9.11	31.69	0	336.78	399	6.16	21.86	0	372.64

Table 2 describes the activity-travel indicators analysed in this paper. At the top panel there are two frequency measures, the number of main and part trips performed during one day. The daily number of main trips is 2.06 for men and 1.95 for women. The difference between men and women, with respect to part trip frequency, is small. Men make 3.31 part trips a day, compared to 3.22 for women. The total distance a person travels during a day is shown at the top of the second panel. This is about 61 kms for men and 43 kms for women. The following lines show how these kilometers are distributed among different modes of transport.[9] The modes in RES have been classified into five categories; walk/bike, local public transport[10], car, train and other. It is obvious that car is the most important transport mode; about 65-70 percent of the total kilometers are traveled by car. The next panel contains temporal information. The average minutes spent on transports are 79 (men) and 69 (women). The start time of the first trip of the day and end time of the last trip are expressed in minutes after midnight in the table. For men the first trips are started at 09.09 on average. For women the corresponding time is 09.44. The last trips end on average at 17.07 (men) and 17.15 (women). The last panel shows how many kilometers from home different activities take place on average. If we compute the distance between the home of the individual and each of the activities he or she is engaged in during a day, we get an average distance of 14.30 kms for men. Women's activities are generally closer to home, 10.57 kms. We also compute this value for each category of activities. It is noticeable that child care is the activity closest to home, while leisure activities are located furthest away. Looking at differences between men and women, we find, for instance, that men work and shop further away from home than women.

3 Theoretical framework

The inter-relationship of the components of the activity-travel pattern are generally not well understood. Many authors have stressed the importance of model development and numerous papers suggesting model approaches

[9] A part trip might consist of several travel elements, where different transport modes are used. We look at the main mode used on every part trip.

[10] Includes local and regional bus, tram, subway and commuter train.

have also been published (see e.g. Recker, 1994; Kitamura and Fujii, 1998)[11]. Activity-based theory postulates that demand for trips is derived from activities and that people act under spatial and temporal constraints created by technological limitations, priorities between activities and interaction with other people. At a conceptual level it is natural to assume that individuals maximize their utility within these restrictions. The possibility of distance work relaxes one constraint and induces re-optimization. To model this process explicitly, or merely express the inter-relationship of the different parts of the activity travel pattern in a stringent way, is a very difficult task however, due to the complexity of the activity-pattern and the underlying decision mechanisms. For empirical analyses of the activity-travel pattern a common approach is structural equation models (SEM), systems of interrelated regression equations (see for example Golob, 2000; Kuppam and Pendalya, 2001). Still, although SEM as a concept is flexible, identification of its parameters requires restrictions and one might end up with a model that is quite simple. Also, it is not always necessary to unwind the whole chain between cause and effect.

Our analysis focus on the effect of distance work on the activity-travel pattern, without much attention to the intermediate steps. It turns out that a simple non-parametric model, with few behavioural assumptions, is sufficient to analyse the questions of this paper. Since the focus of this study is on how distance work affects the travel pattern and not on decision-making behaviour as such, this "black box" approach can be motivated.[12] Our analysis assumes that distance work affects the travel pattern of the distance worker him/herself, but that all other units are unaffected. This is the stable unit treatment value assumption, SUTVA (Wooldridge, 2002). This assumption might be questioned if the share of distance workers becomes so large that a spatial redistribution of various services is caused[13], but with only 5 percent distance workers, as in our case, SUTVA is probably realistic.

Figure 1 illustrates our understanding of the short-term relationship among distance work, gender, socio-economic factors and the activity-travel pattern. Arrows indicate assumed causation. Among socio-economic variables we find

[11] Much of this work has been undertaken within the field of activity-based transport models. For overviews of this field, see Pas (1997) and Ettema and Timmermans (1997).

[12] In the terms used by Mokhtarian and Salomon (2002) this study will be categorized as "accounting" in contrast to more complex "modeling" studies.

[13] Should many people work from their homes, more shops and restaurants located in the residential areas would, for instance, be a realistic scenario.

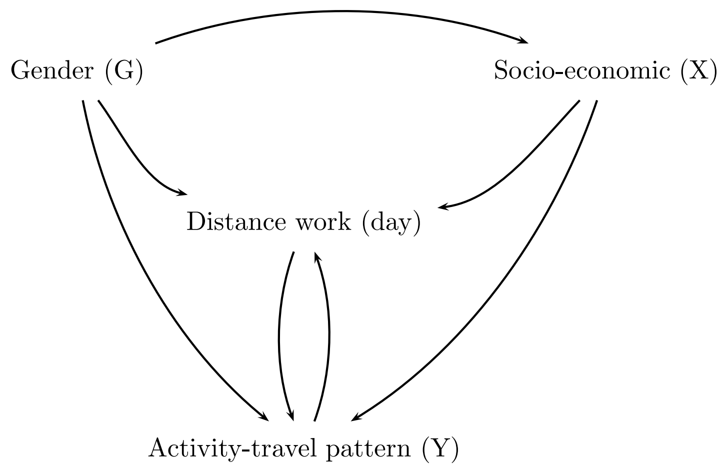

Figure 1: Assumed short-term relation among distance work, the activity travel pattern, gender and other factors. Arrows indicate assumed causality.

many factors that affect the necessity/demand or obstacles for distance work. It is, for instance possible that the family and housing situation are decisive for the choice of distance work a particular day. We also find descriptions of the individual's professional situation among these variables, whether he/she is employed full or part-time, self-employed and in what sector. Together with gender, socio-economic variables are assumed to influence the choice of distance work on a specific day. We also assume that gender might have an effect on socio-economic factors, and therefore influences the activity-travel pattern not only directly but indirectly as well. Gender itself though has no cause, other than pure chance, which is shown by the lack of arrows pointing towards it. The activity-travel pattern is assumed to be a function of gender, socioeconomic factors and distance work.

The short-run (SR) effect of distance work is interpreted as the shift in activity-travel pattern to an unpredicted day with distance work. We might suspect that a distance working day will change the activity-travel pattern in various ways. Not only will commute trips be canceled, but other activities, such as grocery shopping, will have to be done in a non-work context. The short-term effect is illustrated by the arrow from distance work to the activity-travel pattern. But, as indicated by the arrow from the activity-travel pattern, individuals can be assumed to choose distance work

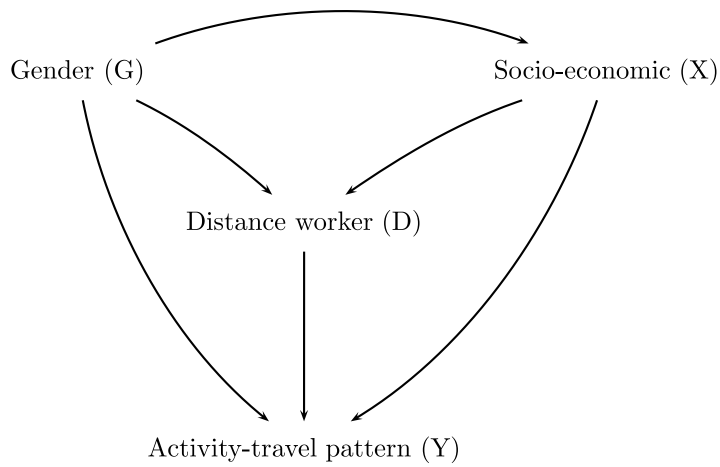

Figure 2: Assumed long-term relation among distance work, the activity travel pattern, gender and other factors. Arrows indicate assumed causality.

on a specific day based on the planned activity-travel pattern. Therefore, using observational data, estimation of the SR distance work effect is impeded by potential reverse causality.[14]

Given the distance work agreement, a long-run (LR) effect might be that the individual moves or engages in activities that are inconveniently located when working at the regular site. Contrary to the SR effect, which we understand as an activity-travel pattern response to an unplanned distance work "shock", the LR effect is the adaptation of the activity-travel pattern, when distance work can be taken for granted. The individual optimizes the activity-travel pattern, finding the best combination of activities, trips and distance work, and eventually a long-run equilibrium is reached. As indicated by figure 2 the long-run effect is not caused by distance work on a particular

[14] To observe travel patterns of distance working days and compare these to non-distance working days or a non-distance working control group have been a common approach in earlier studies. This approach was, for example, used in an early study, "The State of California Telecommuting Pilot Project'" (SCTPP), which has been frequently cited (Koenig et al., 1996). Although travel behaviour on non-distance working days is also reported, the behaviour on distance working days seems to be the result that has gained most attention. Also, an overview of several studies that focus on differences between distance working and non-distance working days is provided by Mokhtarian and Salomon (2002).

day, but by the fact that an individual has a distance-work agreement.

As before, the activity-travel pattern is a function of gender and socioeconomic factors. Among the socioeconomic factors we find factors that might represent both individual preferences and various restrictions. Besides, gender and socio-economic variables determine whether a person is a distance worker or not. Job factors are important for the possibility of working from a distance and other factors determine whether individuals wish to distance work. Being a distance worker or not, given that this opportunity exists, is a matter of individual taste, and not a matter of the activity-travel pattern. Therefore, when we estimate the LR effect, the reverse causality encountered in the SR case is not a problem. In the long run, those who can, and want to, will be distance workers and their activity-travel pattern will be optimized under this condition. If they, in the first place, chose to distance work because they find it beneficial, given their current situation, or because it enables them to move or make other radical "lifestyle" changes, does not matter. Thus there is no arrow from the activity-travel pattern and distance worker in figure 2. In short; the LR effect is the difference between an individual that has been able to adapt his/her life to the possibility of distance work and an otherwise equal individual that lacks this possibility.

4 Estimation

Let $Y(1)$ and $Y(0)$ be some observed dimension of the activity-travel pattern when an individual is and is not a distance worker respectively. Further let W be the binary distance-work treatment taking values 1 or 0 to show whether an *observed* individual distance works or not. The distance-work effect we are interested in is the difference between the observed behaviour of a distance worker and his/her hypothetical behaviour had he/she not been a distance worker. This effect is called *Average treatment of the treated*, ATT, (equation 1).[15]

$$ATT = E(Y(1) - Y(0)|W = 1) \tag{1}$$

[15] An alternative is the The *average treatment effect*, ATE, which is based on non-treated individuals as well. However, ATT works under less restrictive assumptions and seems to be the most frequently used estimator. Also, under assumptions validating ATE, ATE=ATT (Wooldridge, 2002).

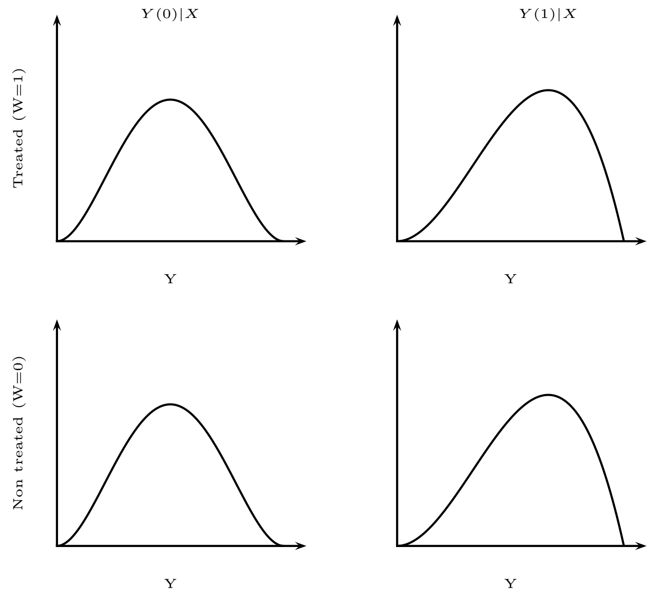

Figure 3: Illustration of CIA principle

4.1 Matching

ATT can not be estimated directly, since $Y(0)|W = 1$ is unobserved, i.e. a *counterfactual*. For $W = 1$ we only observe $Y(1)$. To illustrate the problems of counterfactuals and the matching procedure, we plot four distributions in figure 3. The distributions show $Y(0)$ and $Y(1)$ for the treated (W=1) and non-treated (W=0) groups, respectively.[16] Were it not for the unobserved counterfactuals, we could estimate ATT by a comparison of the upper row columns.

The idea of matching is to substitute observed data for the counterfactuals. If it is assumed that $Y(0)$ is independent of treatment status given X, then $Y(0)|W = 1$ is equal to $Y(0)|W = 0$ if individuals in these two groups are equal/similar in X. Thus, consistent estimates of ATT can be obtained if the conditional independence assumption (CIA) (equation 2) is fulfilled.

[16] The shape, location and dispersion are chosen just for the sake of illustration and do not necessarily have any resemblance to real distributions whatsoever.

$$Y(0) \perp W | X \tag{2}$$

CIA implies that $Y(0)$ will be the same for observed distance workers and non distance workers, given that both groups have the same X. In terms of the figure, CIA means that the two rows of the first column are equal.

To make comparisons possible, X needs to take on values that can be found among both distance workers and non-distance workers. Otherwise the substitution process described above is not possible. Technically this is stated as a requirement for X not to discriminate perfectly between distance workers and non-distance workers:

$$Pr(W = 1|X) < 1 \tag{3}$$

If the inequality does not hold, there are X that are unique for $W = 1$. Then, it is not always possible to find observations from $Y(0)|W = 0$ to substitute for the counterfactuals of the treated, $Y(0)|W = 1$. The analysis is therefore constrained to X where the overlapping condition holds. The range where this is true is called *common support*.

The procedure described above is based on similarity in X. There exists methods to assess similarity even when X is multidimensional, but propensity score matching has been suggested as an alternative. The propensity score is the probability of being in the treated group and is a function of X, $e(X)$. It has been shown that the multi-dimensional vector X can be summarized by $e(X)$ without loss of any information of relevance for the analysis. The assumptions (equation 2 and 3) above can then be reformulated as:

$$Y(0) \perp W | e(X) \tag{4}$$

$$Pr(W = 1|e(X)) < 1 \tag{5}$$

Evaluation of CIA is not possible but we can check the "balance", that is equality in X, between observed and matched cases. The balancing property means that treated and non-treated groups have the same distribution of X, conditional on the propensity score, i.e.:

$$\begin{aligned} Pr(X_i|W_i = 1, e(X_i) = e) &= Pr(X_i|W_i = 0, e(X_i) = e) \\ &= Pr(X_i|e(X_i) = e) \end{aligned} \tag{6}$$

The propensity score is, given the "balancing property", sufficient to control for heterogeneity (Zhao, 2004).

The counterfactuals are estimated as weighted averages over non-distance working individuals that are similar to the distance worker. Several schemes for weight computation are available. We use nearest neighbor matching, where the counterfactual is estimated using an unweighted average over the M most similar untreated individuals.

Let M_i be the M observations that are most similar to individual i. The estimated average treatment effect of the treated is then:

$$\widehat{ATT} = \frac{1}{N_1} \sum_{W=1} \Big(Y(1)_i - \hat{Y}_i(0) \Big) \tag{7}$$

where:

$$\hat{Y}_i(0) = \frac{1}{M} \sum_{j \in M_i} Y_j(0) \tag{8}$$

4.1.1 Inference

Bootstrapping has been a common practice to assess the stochastic variation in the ATT estimator (Sianesi, 2002). Recently, however, it has been shown that this does not produce consistent variance estimates (Abadie and Imbens, 2006). Therefore, we use an analytical formula provided by Abadie and Imbens (2006a). The variance of ATT is estimated as:

$$\begin{aligned} \widehat{Var(\widehat{ATT})} = & \frac{1}{N_1} \sum_{W=1} \big(\hat{Y}_i(1) - \hat{Y}_i(0) - \widehat{ATT} \big)^2 \\ & + \frac{1}{N_1} \sum_{W=0} \Big(\frac{K(i)(K(i)-1)}{M^2} \Big) \hat{\sigma}^2(X_i, W_i) \end{aligned} \tag{9}$$

where M is the number of nearest neighbors, N_1 is the number of treated observations and $K(i)$ is the number of times observation i is used as a match.

$\hat{\sigma}^2(X_i, W_i)$ is the estimated variance of Y. Under heteroscedasticity with respect to X and Y, estimation of this requires a second matching procedure. We assume homoscedastICITY. Then σ^2 is estimated as (Abadie et al., 2001):

$$\hat{\sigma}^2 = \frac{1}{2N_1} \sum_{W=1} \big(\hat{Y}_i(1) - \hat{Y}_i(0) - \widehat{ATT} \big)^2 \tag{10}$$

Substitute this in (9) and rewrite:

$$\widehat{Var(\widehat{ATT})} = \frac{1}{N_1}\sum_{W=1}\big(\hat{Y}_i(1) - \hat{Y}_i(0) - \widehat{ATT}\big)^2 \times \\ \times \Big[1 + \frac{1}{2N_1}\sum_{W=0}\Big(\frac{K(i)(K(i)-1)}{M^2}\Big)\Big] \tag{11}$$

If no non-treated observation is used more than once in the matching process, the scale factor of the second line of equation 11 is 1. Hence, the variance is inflated by reuse of observations. In our case, some observations are reused, resulting in a scale factor of 1.10 for men and 1.13 for women.

5 Analysis

5.1 Propensity score estimation

The first step is to estimate a discrete choice regression model for the choice of distance work and then compute the propensity score, i.e. the predicted probability of being a distance worker. We use simple logit models. Two logit models are estimated, one for men and one for women.

Table 3 shows the estimation of the propensity score[17]. Generally, different factors are important for men and women. The only significant effects that are common for men and women are income and the education level. It seems like both these factors have a stronger effect on women than on men. Furthermore, employment either in real estate, retailing or education increase the probability that a man is a distance worker while, for women, self employment and owning car(s) increase the probability of being a distance worker. We also notice a negative age effect, indicating that the older a woman is, the less probable it is that she will be a distance worker. When it comes to industry, for women, the only significant effect is that employment in health care reduces the probability of being a distance worker. We also estimated a common model for all individuals, which is a restriction compared to the gender-specific models. An LR-test rejects this restriction

[17]That the construction (women) and hotel (men) dummies are excluded is explained by very high shares of zeroes, which results in statistical problems.

Table 3: Logit model - the relation between the propensity score (probability to be a distance worker) and socio economic variables

	Men		Women	
	β	t	β	t
Constant	-5.08	-8.09	-6.64	-8.11
Part time	-0.36	-0.76	-0.29	-1.16
Self employed	0.13	0.57	1.26	3.83
Age	-0.00	-0.48	-0.02	-2.27
Income (100000 SEK)	0.10	2.48	0.30	4.68
Married	0.15	0.68	-0.28	-1.04
Household size	0.01	0.14	0.08	0.95
Drivers licence	-0.16	-0.45	0.61	1.25
No. of cars	-0.09	-0.88	0.41	3.41
House	0.32	1.69	-0.06	-0.28
Education level	0.67	5.88	1.15	6.90
Construction*	0.03	0.07		
Electric/gas	0.65	0.89	1.07	1.15
Real estate	1.01	2.23	0.33	0.75
Finance	0.72	1.19	0.17	0.26
Hotel			-1.15	-1.06
Health care	0.57	1.13	-0.91	-2.07
Farming	0.49	0.74	-0.47	-0.42
Public admin	0.55	1.09	-0.55	-1.02
Retail	0.90	1.97	-0.22	-0.45
Publ pers serv	0.70	1.28	0.28	0.56
Manufacturing	0.15	0.35	-0.07	-0.15
Transport	0.48	0.95	-0.15	-0.25
Education	1.23	2.57	0.25	0.58
LR	130.21		187.11	
p	0.000		0.000	

* The reference sector is the fishing industry.

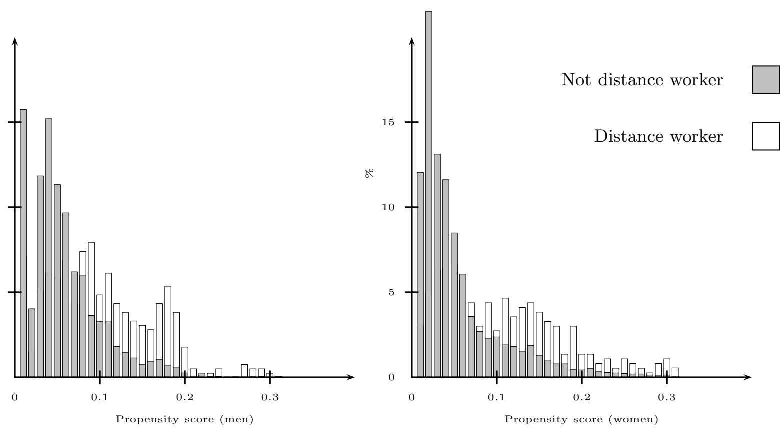

Figure 4: Propensity scores, i.e. the estimated probability of being a distance worker. The distributions are truncated to the right.

in favor of separate models[18]. The general conclusion therefore is that the factors explaining distance work are different for men and women.

6 Validating the overlapping condition

Validity of the overlapping condition (5) can be assessed by various methods. Imbens (2004) recommends that the propensity score distributions for both groups are compared. Figure 4 shows the propensity score for men and women separated into distance workers and non-distance workers. That the distributions overlap indicates that the overlapping condition is satisfied. What the overlapping distributions tell us is that the covariates do not discriminate perfectly between distance workers and non-distance workers, although distance workers have a higher propensity score in general. In other words, it is possible to find distance workers and-non distance workers that share covariate values.

[18]The gender specific models estimated here are equivalent to one model with all 24 regressors plus 24 gender/regressor interaction terms. A common model that does not take gender differences into account thus has 24 restrictions.

7 Sensitivity analysis

The balancing property (equation 6) requires X to be independent of treatment status conditional on the propensity score. Here we will see whether the matching procedure levels the differences between distance workers and non distance workers. We do this by a mean value comparison between distance workers and their matched counterparts. An absence of significant differences, or at least reduced differences, will be taken as evidence of a successful matching process.

We use the absolute standardized bias (ASB), a measure that can be computed before as well as after matching. The bias is the difference of the sample means of the treated and non-treated groups as a percentage of the square root of the average of their variances (Sianesi, 2002).[19] The ASB is shown in table 4, which has two sections, each with five columns. Each section contains descriptions of men and women separately and starts with a column describing the observed distance workers (Dw) in terms of mean values of the socio economic variables. This is followed by a corresponding column for observed non distance workers (NDw). ASB^a describes the bias of an estimator based on observed Dw and NDw. The column named M contains mean values for the matched control individuals, i.e. the mean to equation 8. It is followed by ASB^b, the bias caused by post matching differences in socio economic variables. ASB^a and ASB^b are summarized by the median in the lower part of the table. As can be seen, matching reduces bias considerably (median ASB^b is lower than median ASB^a). Although we can observe a general reduction in bias, some heterogeneities remain after the matching. In particular this is true for income and education level where, after matching, ASB is above 35 in all cases. The matching procedure also fails to reduce some imbalances in the employment sector. Distance workers are, for instance, conditionally over-represented in real estate and education and under-represented in health care (women) and manufacturing (men). Also worth noticing is the number of cars and the share with a drivers' license. Among men the post match biases are small for these variables but for women they are 15 percent. Distance working women have more cars and are more plausible driving licence possessors than their matched counterparts.

[19] A common t-test would probably be an alternative to this procedure, but we use ASB since it seems to be the convention. The mathematic formulas used to compute ASB (see footnotes to table 4) are provided by Fredriksson and Johansson (2003).

Table 4: After match balance (averages). Dw=observed distance worker, NDw=observed non distance worker, M=match (estimated counterfactual)

	Men					Women				
	Dw	NDw	ASB[a]	M	ASB[b]	Dw	NDw	ASB[a]	M	ASB[b]
Part time	0.02	0.03	9.1	0.03	5.2	0.15	0.30	37.6	0.23	19.0
Self employed	0.10	0.10	0.2	0.10	0.3	0.10	0.03	27.2	0.07	12.2
Male	1.00	1.00	0.0	1.00	0.0	0.00	0.00	0.0	0.00	0.0
Age	43.30	42.33	8.2	42.51	6.7	41.73	43.39	15.4	42.71	9.0
Income/10000	35.00	26.00	54.2	27.00	47.4	27.00	20.00	69.5	23.00	36.4
Education level	2.52	2.05	64.7	2.22	41.0	2.69	2.16	80.8	2.40	43.4
Construction	0.03	0.07	18.3	0.06	10.9	0.00	0.01	15.5	0.00	8.6
Electric/gas	0.01	0.01	1.8	0.01	0.5	0.01	0.00	10.3	0.00	6.8
Real estate	0.20	0.10	26.3	0.13	17.1	0.17	0.08	28.5	0.13	13.2
Finance	0.02	0.01	6.5	0.02	3.5	0.02	0.02	4.4	0.02	1.8
Fishing	0.00	0.00	2.4	0.00	1.3	0.00	0.00	0.0	0.00	0.0
Hotel	0.00	0.01	15.2	0.00	8.0	0.00	0.02	13.9	0.01	7.5
Health care	0.06	0.05	6.5	0.06	3.4	0.15	0.33	41.2	0.24	20.9
Farming	0.01	0.02	4.7	0.02	3.2	0.00	0.00	0.8	0.00	0.9
Public admin	0.06	0.05	4.9	0.06	1.8	0.04	0.06	7.6	0.05	3.0
Retail	0.14	0.12	6.3	0.13	2.5	0.07	0.10	9.7	0.08	4.9
Publ pers serv	0.04	0.03	1.3	0.04	0.1	0.06	0.04	9.7	0.05	4.1
Manufacturing	0.16	0.29	30.4	0.24	18.4	0.09	0.10	2.7	0.10	1.6
Transport	0.05	0.08	8.5	0.07	5.7	0.03	0.03	1.4	0.03	0.7
Education	0.13	0.04	31.0	0.07	21.5	0.22	0.10	34.4	0.15	18.9
Married	0.80	0.75	13.7	0.77	8.8	0.77	0.75	3.1	0.77	0.1
Household size	2.90	2.75	11.4	2.80	7.6	2.86	2.73	10.5	2.80	4.7
Drivers licence	0.95	0.94	6.1	0.95	3.2	0.96	0.89	28.3	0.92	15.3
Nr cars	1.33	1.34	1.3	1.33	0.0	1.47	1.24	31.7	1.36	15.1
House	0.70	0.64	12.1	0.66	7.6	0.64	0.63	3.2	0.64	1.3
Median ABS			8.2		5.2			10.5		6.8
Nr of observations			219					145		

[a] $ABS(k) = 100 \cdot |\frac{1}{n}\sum_{i=1}^{n} x_i^k - \frac{1}{N}\sum_{c=1}^{N} x_c^k| / \sqrt{(s^2(x_i^k) + s^2(x_c^k))/2}$

[b] $ABS(k) = 100 \cdot \frac{1}{n}\sum_{i=1}^{n} |x_i^k - x_c^k| / \sqrt{(s^2(x_i^k) + s^2(x_c^k))/2}$

7.1 The distance work effect

For every activity-travel indicator, Y, we compute the average treatment effect of the treated for men and women, $ATT_g, g = men(m), women(w)$, which is interpreted as the long run distance work effect. To summarize potential gender differences, we define the total gender effect, TGE, which is simply the difference in ATT between men and women:

$$\begin{aligned} TGE &= E\Big[(Y_m(1) - Y_m(0)|X_m) - (Y_w(1) - Y_w(0)|X_w)\Big] \\ &= ATT_m - ATT_w \end{aligned} \tag{12}$$

The total gender effect, TGE, shows how gender differences in the activity-travel pattern changes in response to distance work. If TGE is zero, the relation between the activity-travel pattern of men and women does not change due to distance work, that is both sexes are affected similarly. The interpretation of a TGE different from zero is that the impact from distance work is different for men and women.

The estimated long run distance work effects are found in table 5.[20] A striking feature is that very few of the estimated effects are significant. For women the long run implications of distance work is that purchases and child care are moved closer to home. For purchases the effect is large; distance work reduces the average distance between the home and shopping places by 11.39 kms. Child care will be 1.65 kms closer to home (on average) when a woman starts distance working. There are also close to significant (p-values 0.06 and 0.13) effects on the start time of the first trip and the end time of the last trip. Distance working women start their first trip 34 minutes earlier and end their last trip 39 minutes earlier than they would have done had they not been distance workers. For men we find no significant effects at all! The closest to significant effects indicates that distance work for men might lead to later arrivals from the last trip and leisure activities that are located further from home (p-values 0.13 and 0.27).

[20] As noted above our data consists of travel diaries evenly distributed over all seven days of the week. Based on the reasoning about long-run effects, we find it proper to look at transports in general. However, we have found that a restriction to Monday-Friday does not change the conclusions of this study. As can be seen in table 6 in the appendix, the same effects are significant, and the sizes of the effects are quite similar to those based on all seven days.

As is shown by the TGE:s, distance work means that men end their last trip later and women earlier in relation to each other. In addition, the difference in distance between the home and child care increases, so that women are closer to child care than men. Two additional TGE:s can be worth mentioning even though they are not significant. Distance work might mean that the gender differences in distance between home and places for activities in general and specifically leisure activities increase (p-values 0.14 and 0.10). In addition, although few TGE:s are individually significant, in general distance work affects men and women in different ways. We perform Hotelling's test (Mardia et al., 2003) on each of the four panels in table 5. The hypothesis is that, within each panel, all distance work effects are equal for men and women, i.e. all TGE:s are zero. This hypothesis, however, is rejected in all four cases.[21]

8 Conclusions

We have shown how distance work affects the activity-travel pattern of men and women. Some interesting conclusions can be drawn from this analysis, although very few significant effects have been found. First we have found that distance work to a large extent is explained by different factors for men and women. So even before the activity-travel pattern is scrutinized, we have an indication of gender differences. The only significant effects that are common for men and women are income and the education level, which are both positively related to distance work. Furthermore, employment either in real estate, retailing or education increase the probability that a man is a distance worker while, for women, self employment and owning car(s) increase the probability of being a distance worker. We also notice a negative age effect, indicating that the older a woman is, the less probable it is that she will be a distance worker. When it comes to industry, the only significant effect for women is that employment in health care reduces the probability of being a distance worker.

We estimate long-run effects from distance work, i.e. the adaptation of the activity-travel pattern when distance work can be taken for granted. The individual optimizes the activity-travel pattern, finding the best combination of activities, trips and distance work. Eventually a long-run equilibrium is

[21] The test procedure is not entirely adequate. It should probably be adjusted to account for extra variability introduced by the matching procedure.

Table 5: Long run distance work effects (ATT nearest neighbor)

	Men		Women			
	ATT	t	ATT	t	TGE	t
Main trips per day	0.10	0.81	0.08	0.63	0.02	0.11
Part trips per day	0.03	0.12	0.09	0.37	-0.06	-0.17
Traveled distance (km/day)						
Total distance	0.06	0.20	0.07	0.26	-0.01	-0.02
Walk, bike	0.32	0.33	1.70	0.63	-1.38	-0.48
Local public	8.38	1.12	-4.5	-1.08	12.88	1.51
Car	2.62	0.83	3.50	0.78	-0.88	-0.16
Train	-6.77	-0.72	0.31	0.03	-7.08	-0.47
Other	4.61	0.39	1.08	0.10	3.53	0.22
Temporal information (min)						
Start time first trip	-10.48	-0.72	-34.19	-1.90	23.71	1.02
End time last trip	34.83	1.53	-39.08	-1.53	73.91	2.16
Total travel time	5.23	0.77	0.84	0.11	4.39	0.44
Average distance from home (km)						
Activities total	6.17	0.83	-6.2	-1.57	12.37	1.47
Work	8.17	0.88	0.49	0.36	7.68	0.82
Purchases	3.24	0.27	-11.39	-4.19	14.63	1.20
Child care	0.09	0.14	-1.65	-3.62	1.74	2.26
Leisure	11.02	1.10	-11.95	-1.23	22.97	1.64
Drive another person	-0.76	-0.44	0.73	0.37	-1.49	-0.57

reached. It is found that in this process the reduction in commute trips, that is a plausible effect of distance work, is counterbalanced by other effects. No significant effects have been found showing that distance work decreases traveled distance. Hence, with regard to transport related environmental problems, distance work does not seem to be a solution.

The new possibilities created by distance work result in other changes though. We have found that, for women, in some instances distance work changes how far from home different activities take place significantly. For women, child care is closer to home as an effect of distance work. Besides, women who are distance workers make their purchases closer to home. Thus, in some sense it seems that distance-working women adopt a more "local" lifestyle. For men we find no significant effects at all. We have also computed how the activity-travel pattern differences between men and women change due to distance work. Two of these total gender effects are individually significant, end time of the last trip and the distance between home and child care. Tests performed on groups of total gender effects also show that, in general, the impact of distance work on the activity-travel pattern is different for men and women.

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Appendix

Table 6: Long run distance work effects (ATT nearest neighbor). Results if the analysis is restricted to weekdays (Monday-Friday)

	Men		Women			
	ATT	t	ATT	t	TGE	t
Main trips per day	0.19	1.29	0.10	0.70	0.09	0.44
Part trips per day	0.26	1.08	0.22	0.80	0.04	0.11
Traveled distance (km/day)						
Total distance	-0.31	-1.14	0.07	0.22	-0.38	-0.90
Walk, bike	0.61	0.48	2.02	0.60	-1.41	-0.39
Local public	12.74	1.35	1.49	0.32	11.25	1.07
Car	3.22	0.75	5.71	1.01	-2.49	-0.35
Train	-2.35	-0.21	4.43	0.36	-6.78	-0.41
Other	13.91	0.96	13.73	1.00	0.18	0.01
Temporal information (min)						
Start time first trip	-2.24	-0.18	-22.44	-1.32	20.20	0.96
End time last trip	37.82	1.52	-33.56	-1.35	71.38	2.03
Total travel time	10.57	1.33	10.23	1.23	0.34	0.03
Average distance from home (km)						
Activities total	0.42	0.08	-4.62	-1.05	5.04	0.72
Work	1.32	0.41	0.91	0.68	0.41	0.12
Purchases	-5.31	-1.33	-9.02	-3.07	3.70	0.75
Child care	0.09	0.14	-1.65	- 3.62	1.74	2.26
Leisure	12.02	1.09	-3.70	0.34	15.72	1.01
Drive another person	-4.04	-1.33	1.25	0.65	-5.30	-1.47