Matching Home and Work:
Job Search, Contacts, and Travel

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Dedication

To my parents,

Yoni and Sebli,

who have shaped me into

the person that I am

and

To Selam,

for her love.

Abstract

Transportation is closely tied to choices: those that have to do with location - where to live, work and play; temporal choices - when to engage in certain activities; the choice of mode - how to get to those activities and so on. The choice of home and work locations is especially important since these are relatively long term fixtures and can significantly influence everyday travel decisions. Often a person's day starts at home and ends at home. For many workers, other daily activities are constrained by the time they spend at their employment locations. Decisions related to home-work travel can also influence other choices such as short term activity locations. Understanding the link between home and work is therefore an important part of policy making to manage or accommodate travel demand.

Traditionally, the approach taken by transportation professionals to match home and work locations has been to use trip distribution models, the most commonly used of which has been the gravity model. These models, which use aggregate zonal variables to match home and work, are still widely used by many planning organizations. This framework, while very useful in predicting aggregate trip distribution, overlooks much of what happens as the connection between people's home and work are established.

This dissertation poses the link between home and work as an outcome of a search process for employment, where both searchers (workers) and employers try to match one another through advertising, search, screening, offers and decision making. It proposes a framework for matching home and work at a disaggregate level that follows the

job search process. Empirical sections pay close attention to search methods as these can inform the geographic scope of opportunities searchers know of. Distinctions between different search methods and the related commute outcomes are illustrated using data collected for this study. The role of contacts in general, and neighborhood level contacts in particular, in matching home and work is also investigated using different data sources. An agent based model of job-worker matching based on the proposed framework is also developed and tested using data from Minnesota.

While the overall emphasis is on a disaggregate approach and moves away from geographic (zonal) aggregation of decision makers, the study of contacts and their role serves to illustrate that travel and destination decisions are not independent of those around us. Focusing on the individual decision maker and following the process of job-worker matching can allow for models that are much more sensitive to changes in policy variables as they can accommodate the variability of tastes and responses among decision makers. On the other hand, the consideration of contacts, including those that may be neighbors, leaves the door open for consideration of behavior that may arise from interactions with others.

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η_{ic}: The log odds of using search method i relative to using contacts, where i = 1 for formal, 2 for internet, and 3 for newspapers. (ch. 4)

γ: the annual discount rate. (ch. 6)

γ_o: The rise in offer wages by employers, $\gamma_o \sim U(0, \gamma_{o,max})$. (ch. 6)

γ_c:The decline in expected wages when unemployed, $\gamma_c \sim U(0, \gamma_{c,max})$. (ch. 6)

γ_r: The rise in wages each year a person remains employed, $\gamma_r \sim U(0, \gamma_{r,max})$. (ch. 6)

π_l: The probability that a meeting occurs out-of-home. (ch. 7)

ρ: The tie density of the work (W^m) matrix. (ch. 3)

A: age of the respondent (ch. 7)

A_j : Age at the time of taking job. (ch. 4, 5)

A_b: the median age in the block. (ch. 3)

Ac_b: the gravity based accessibility measure of the TAZ that the block is in (/1000). (ch. 3)

C: the count of matched pairs (0-0 or 1-1). (ch. 3)

C_{11}: the count of matched 1-1 pairs. (ch. 3)

C_l: Whether applicant j used an influential contact. (ch. 7)

C_r: Close contact (identified as family or close friend). (ch. 7)

C_{p3}: proportion of contacts in 3 miles of respondent's home. (ch. 4, 5, 7)

C_s: Number of close contacts (interact with twice a month or more, and don't live in the same house as you). (ch. 4)

D is the count of unmatched pairs (0-1 or 1-0). (ch. 3)

D_{mt}: the home to meeting location distance. (ch. 7)

D_{hw} : Home-to-work distance (dependent variable for model 5.1). (ch. 5)

E: education (0=high school graduates, 1=above High school). (ch. 4, 7)

E_m: Was the person employed at the time? (ch. 4)

F: does the person telecommute? (1=yes). (ch. 7)

F_b: the average family size in a block. (ch. 3)

G: Gender (male = 1, female = 0). (ch. 4, 7)

H_b: the percentage of one person households in the block. (ch. 3)

H^m: the home adjacency matrix. (ch. 3)

H: household size (1=single, 0=otherwise). (ch. 7)

I: search intensity, $I\ simU(I_{min}, I_{max})$. (ch. 6)

I_h: Household income. (ch. 4)

J: Jaccard coefficient. (ch. 3)

J_c : Job found through contacts. (ch. 5)

J_f : Job found through formal means. (ch. 5)

J_i : Job found through the Internet. (ch. 5)

J_n : Job found through newspaper advertisements. (ch. 5)

J_q: the job-class for a job/position. (ch. 6)

L_{NW} : Dummy variable for home location in the north west suburbs of the Twin Cities. (ch. 5)

L_{SW} : Dummy variable for home location in the south/south east suburbs of the Twin Cities. (ch. 5)

S_M: Simple matching coefficient. (ch. 3)

M: meeting purpose (1=leisure, 0=otherwise). (ch. 7)

N_w: Number of working days in a year. (ch. 6)

NPV_{kt_e}: the net present value as a result of being at job k for an expected tenure of t_e. (ch. 6)

O_b: the percentage of owner occupied households in the block. (ch. 3)

p^b: The probability that a worker chooses a job offer as the best among competing offers. (ch. 6)

p_{rel}: is the probability of wanting to change jobs. (ch. 6)

P_c: proportion using contacts to find their job. (ch. 6)

P_{cI}: proportion of influential contacts among contacts used to find employment. (ch. 6)

Q: Neighborhood quotient, measuring if the respondent's block group has a higher proportion of food, entertainment, and retail businesses as compared to the metropolitan area as a whole. (ch. 7)

Q_a: is a random draw from a uniform distribution with a range of \$0 to \$5,000. (ch. 7)

Q_p: is a random draw from a uniform distribution with a range of \$0 to \$10,000. (ch. 7)

R_c : Do you currently rent your residence? (yes=1). (ch. 5)

R_b: The majority race in the block. (ch. 3)

S_c: the skill-class for a worker. (ch. 6)

tol: A global tolerance level among searchers for under or over-qualification. (ch. 6)

T : Home-to-work travel time (dependent variable for model 5.2). (ch. 5)

T_d: The daily travel cost (round trip travel time to work) (in hours). (ch. 6)

T_{mt}: Meeting duration (in 10 minute increments). (ch. 7)

t_e: the expected tenure at a new position. (ch. 6)

t_r: tenure at current employment. (ch. 6)

$\bar{t_r}$: the tenure for the population beyond which the probability to start searching for another job declines below 0.5. (ch. 6)

u_o: the number of iterations a positions has stayed open. (ch. 6)

u_s: the number of iterations an unemployed worker has been searching. (ch. 6)

VOT_k: value of commute time for person j at job k (assumed $0.6W_k$). (ch. 6)

W_{disp}: indicates whether there is wage dispersion at a given skill level. (ch. 6)

W: the current wage received by a searcher. (ch. 6)

W_m: the minimum wage below which a searcher rejects offers. (ch. 6)

W_o: the wage offer by a job. (ch. 6)

W_e^u : the expected wage at time t, when a person is unemployed. (ch. 6)

W_e^e: the expected wage at time t, when a person is employed. (ch. 6)

W^m: the work adjacency matrix. (ch. 3)

W_{end}: weekend (yes=1). (ch. 7)

Y_h: tenure at home (years). (ch. 7)

Y_{hj} : Number of years at current residence at the time of taking the job. (ch. 5)

Y_j: How long ago was the job search done (years)? (ch. 4)

Chapter 1

Home-Work Matching

1.1 Introduction

Transportation is closely tied to choices: those that have to do with location - where to live, work and play; temporal choices - when to engage in certain activities; the choice of mode - how to get to those activities and so on. Understanding how these decisions are made is key to the success of programs that aim to manage or accommodate travel demand. The choice of home and work locations is especially important since these are relatively long term fixtures and can significantly influence everyday travel decisions. Often a person's day starts at home and ends at home. For many workers, other daily activities are constrained by the time they spend at their employment locations. Decisions related to home-work travel can also influence other choices such as short term activity locations.

The relationship between home and work has been an important research area for economists, urban geographers, sociologists and others who have each brought their fields experience to the understanding of how workers and jobs are matched. Traditionally, the approach taken by transportation professionals to match home and work locations has been to use trip distribution models. These models are part of the widely used four-step transportation planning process comprising steps of trip generation, trip distribution, mode choice and route assignment. Trip distribution models such as the gravity model, which use aggregate zonal variables to match home and work, are still widely used by many planning organizations. While this framework is very useful, it overlooks much of what happens as the connection between people's home and work are established.

The connection between home and work is the outcome of interactions between employers and job seekers that have different goals. The employer is often motivated by increased productivity through the addition of new staff to perform particular duties(1), while the employee has aims of increased income and other long term goals that have to do with their future ambitions. Each searches for their best fitting counterpart and hope the match they find takes them forward in the fulfillment of their respective goals. In addition to geographic locations of jobs and workers, this matching process is structured by how employers advertise and recruit, how workers search and weigh alternatives, and the limited amount of information that is available to each searcher about opportunities.

While the gravity model will be discussed in more detail in the next chapter, here we will briefly discuss some aspects to motivate this study. The emphasis of the gravity model is on distributing the trips produced and attracted at the zonal level in the trip generation step of the four step process. In general the values from the trip generation step depend on some measure of size of the zones in consideration, be it in population, household composition, employment size etc. The distribution step incorporates these values along with a measure of travel cost to distribute trips in such a way that closer locations get more trips and farther locations get fewer and larger attractors get more and smaller ones get fewer of the trips from any given zone. In general this pattern is consistent with what is observed. A closer consideration however suggests that measures of size and time alone may be misleading. Mismatches in a trip generating area's workforce and an employment area's firms for example may not be reflected in the models output. Though later models have attempted to segment population or add correction factors to adjust for such inconsistencies, such approaches still ignore the process by which matching takes place. This dissertation argues for a more disaggregated approach that considers the process of matching explicitly. In the next section, a framework for matching home and work is proposed. That is followed by a description of how the dissertation is organized. Proceeding chapters will look at different aspects of the home-work connection as well as develop and test an agent-based model of job-worker matching based on this framework.

1.2 A Framework of Matching Home and Work

There are several key elements in the matching process that are instrumental in increasing the chances for some to get employed while reducing the chances for others to get access to the same job even when people share similar skill sets. Let us consider a relatively simple system where employers advertise positions, searchers apply to these positions, employers then make an offer to the best candidate and the employee decides to accept or reject the offer. For a match to be successful, the job seeker must have access to information that the position is open to begin with. Second the searcher must have skills that reasonably match the position. The searcher must also be able to meet the screening criteria of the employer. And finally for those that receive offers, the offer has to be better than what the searcher sees as their best alternative. Each of these steps creates both barriers and opportunities to different types of people from getting any given job that is available.

The path the employer follows in recruiting for example can effectively block out a segment of the population or create systematic bias as to who receives that information. For example, recruitment procedures that use employee referrals would focus on people who are in someway connected to existing employees (1); advertising in a subset of local labor markets can exclude others that may have similar skills but reside outside of the focus area (2). Once applications from job seekers are received, firm screening procedures also impact who gets particular opportunities. In addition to skills, education and experience, employers can use other ways to make judgements about the quality of the applicant's match. A referral is one way this is achieved, and other methods can include the use of demographic proxies to get at the same information. The latter for example is the focus of many studies that look at discriminatory behavior of employers in regards to a variety of factors ranging from race and gender (3, 2) to weight and smoking.

On the worker's side, what method of search one would use can lead to missed opportunities. In addition, their judgement as to whether the opportunities they know about are worth pursuing given their skill set and goals will impact the offers they eventually receive. As will be shown later, search methods can also be related to the location of the offers that searcher receives relative to their residence. Finally, those who receive offers have to weigh among them by looking at wages, future prospects and other alternatives.

The contrasts between the process described above and the traditional approach can be depicted as shown in figures 1.1 through 1.4. Figure 1.1 represents the traditional framework where the probability of searcher i taking a position with firm/opportunity j is a decreasing function of travel time between the two. The framework proposed here frames the question differently and proposes at least four basic requirements from the searcher's perspective for a match to be successful. First, is that i ought to know about j. Information about j can reach the searcher (i) through contacts as depicted in figure 1.2 or through the use of other search methods including using recruiters, the web, or personal visits, among others.

Second, while information about j is a necessary condition for i to pursue a given opportunity, the searcher should also have the skills (and experience) j requires, sufficient to believe there is a reasonable chance for a match. Figure 1.3 represents areas with opportunities that match this criteria. A third consideration is that j's wages should satisfy i's requirements. As represented in figure 1.4 several areas match the wage requirements, but fewer opportunities satisfy both skills and wages. Finally i ought to have a mechanism to weigh between competing offers that match its criteria. This weighing will include attributes of the opportunities as well as the travel costs.

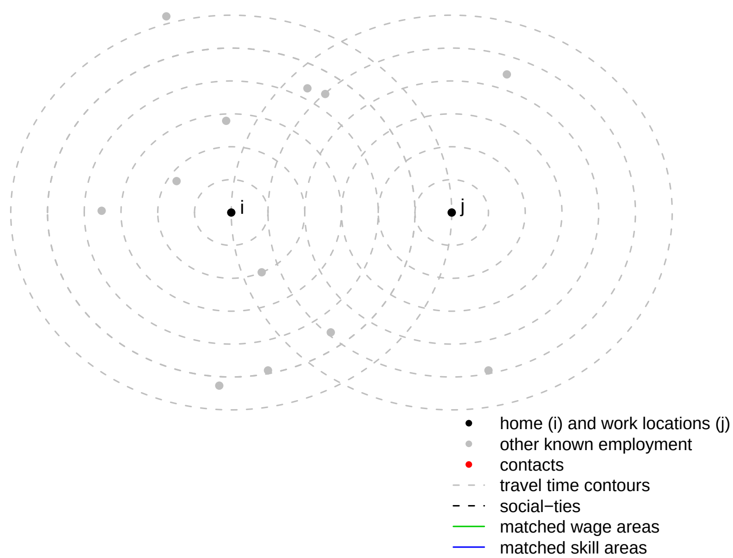


Figure 1.1: The traditional framework: farther opportunities are less likely

As mentioned earlier, zonal level matching as used in the traditional modeling framework tries to bring together workers and employees while overlooking the complexity of the job-worker matching process. In fact when employing gravity models, work trips are treated not much differently from other types of trips where zonal produced and attracted trips and travel time primarily account for the O-D estimates. While production and attraction estimates do depend on the demographic variables as well as measures of opportunities at origin and destination zones, few other variables account for systemic patterns of which individuals go where. In part the use of correction factors is necessitated by the considerable simplification of the modeling framework. The alternative framework proposed here for example ensures that pursued opportunities

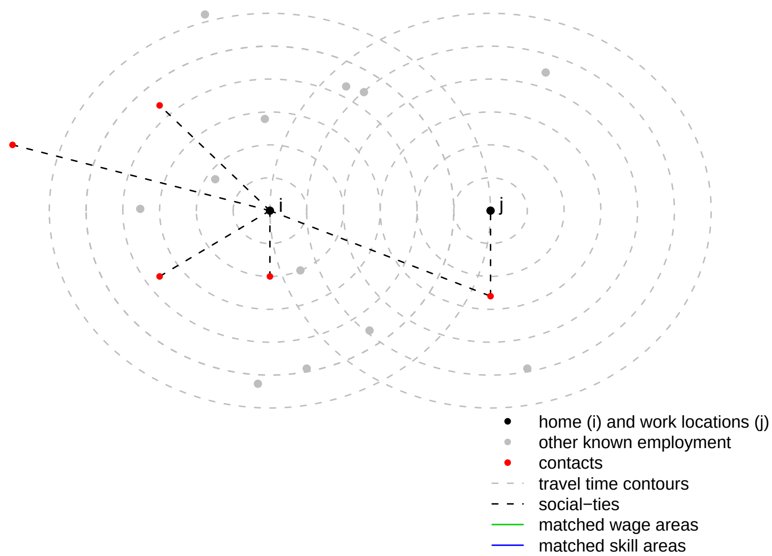


Figure 1.2: Searcher has to know of opportunities (through contacts or other means)

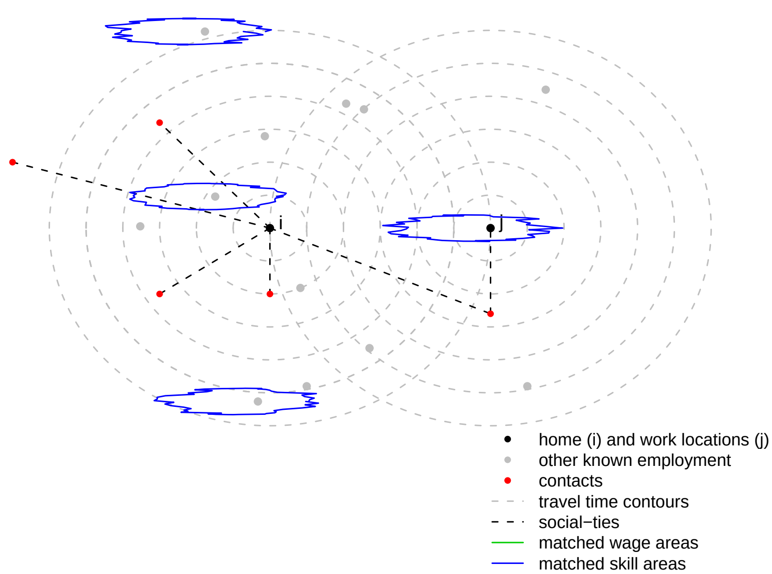


Figure 1.3: Opportunities should match the skill of the searcher

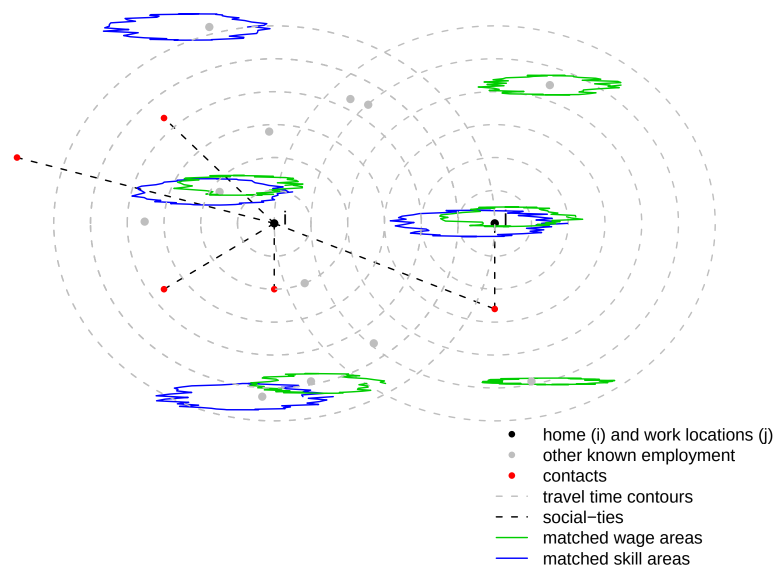


Figure 1.4: Opportunities should satisfy the skills and desired wage of the searcher

are a reasonable match to the searchers skills. In addition, it is flexible enough for the addition of other layers that are found to be important in matching workers to their work destinations.

Overall, this dissertation looks into the details of home-work matching with a focus on the role played by different search methods and their effect on travel outcomes. The search methods explored include contacts, formal means, newspapers, and the internet. The changes that internet technology has brought to job search and its effects on distance outcomes are investigated. The role of contacts is especially paid greater attention both because contacts contribute to a significant amount of job finding and because they can influence residential as well as other location decisions. The role of contacts is also explored in the location and duration choices for meeting locations in chapter 7; issues that are important to the newer generation of travel demand models - the activity based models. In addition chapter 6 employs the above framework to match workers and jobs and tests it using data from the Twin Cities.

While the emphasis is on a disaggregate approach, the study of contacts and their role serves to illustrate that travel and destination decisions by and large are not independent of those around us. Focusing on the individual decision maker and following the process of job-worker matching can conceivably allow for models that are much more sensitive to changes in policy variables as they can easily capture the variability of responses among individual decision makers. On the other hand, the consideration of contacts including those that may be neighbors leaves the door open for consideration of aggregate behavior that may arise from interactions with others.

1.3 Organization of the Dissertation

This dissertation is organized as a set of independent chapters. Two general sections are presented. Chapters 3 through 6 look at the home-work connection and the roles played by different search methods, primarily social contacts. Chapter 7 looks at the role of social contacts in meeting location choice as well as time allocations. Within the first section, separate chapters consider the role of social networks in work finding and residence finding (chapter 3), the job search path and changes experienced over time (chapter 4), the relationship between job search path and commute, and the connections with residential tenure and relocation (chapter 5). Chapter 6 proposes an agent based model of job-worker match and tests it using the 2000 Minnesota Travel Behavior Inventor (TBI) data. Chapter 7 considers the role of contacts in social meeting location choice and duration. Brief summaries of each chapter are given below.

In Chapter 2, the existing literature on travel demand analysis, job search, relocation and tenure, meeting arrangements are reviewed briefly. The emphasis is on travel demand models, and job-searcher matching with an emphasis on the role of contacts. The coverage is broad in part because contacts have a role to play in different spheres of individual decisions. Some of these are well explored in the literature (for example in job search), others are just starting to be explored (travel for social activities for example). All are important in one type of travel decision or another.

Chapter 3 discusses the possible roles that work and home-neighborhood social networks can play in finding residences and employment respectively. It posits that residential neighborhood level social networks and workplace social networks are important elements of work and home finding and lead to measurable levels of home-work co-location. Workplaces and neighborhoods are presented as centers of social network organization where information about neighborhoods or workplaces are exchanged. The outcome of such a process would be the existence of significant home-work co-location. The chapter will empirically test for such aggregation at home and work using areas of the Twin Cities employing the Longitudinal Employment-Household Dynamics (LEHD) and Census data.

Chapters 4 and 5 expand the job search process to include formal, internet, and newspaper searches in addition to contacts in job finding. These chapters and chapter 7 employ data collected from Twin Cities residents. In chapter 4 we look at which individuals are likely to use any one method to find work. The chapter explores the changes in technology that have happened in the past two decades and how job search has changed.

In chapter 5 we explore the relationship between job search path and work location as well as relocation decisions. Here we explore what differences exist in the residential relocation decisions among people who used the different search methods to find their latest employment. Finally the impacts of changing work on commuting are explored. Throughout the role of contacts, technology and formal means in finding work are explored.

Chapter 6 proposes an agent based model of job-worker matching. The model proposed simulates independent jobs and agents that interact with one another through advertisement of jobs, applications, screening, offers and employment. Job and skill criteria as well as wage offers and travel time are used as a basis of decision making. The proposed model is then tested using data from the 2000 Travel Behavior Inventory.

Finally, chapter 7 turns to social meetings. Social meetings are explored using one week data that is collected in from Twin Cities residents. Here the motivation is understanding the frequency and where, when, for what purpose social meetings occur and their travel outcomes. Interactions between relationship quality, meeting duration, home to meeting location distance, household constraints and neighborhood quality are considered with the aim of understanding the interactions among one another.

Chapter 2

Literature Review

2.1 Introduction

In this chapter, we will primarily review the home and work location choices of people and how they have been approached in different fields. This topic has received interest from economists, urban geographers, sociologists as well as planners and transportation modelers. In reviewing this broad topic, we will start with discussions of travel demand models and how they have evolved over time. The topic of home-work matching as approached traditionally in transportation as well as in different areas is discussed. Search models, models of urban structure, residential location models are also discussed briefly. That is followed by a discussion on job finding, and housing location choice.

2.2 Travel demand models

Computerized travel demand models were first developed in the 1950s. Early models of travel demand were geared toward new infrastructure and facility improvement analysis, and focused on aggregate formulations of the problem with little behavioral basis (4). Today much more is expected of these models in addressing issues ranging from emissions and air quality to congestion mitigation. This increasing demand along with advances in modeling techniques have led to a gradual evolution, and today the focus of models has become on the individual decision maker at least in research. In practice the aggregate models are still widely in use.

2.2.1 Evolution of Travel Demand Models

The first fully constituted urban transportation study was the Detroit Metropolitan Area Traffic Study (DMATS) undertaken between 1953-1955 (4). Since then the traditional four step urban transportation planning model had become the workhorse of transportation professionals. The process includes the sequential steps of trip generation, trip distribution, mode choice, and traffic assignment.

In its initial formulation, each step included a model or set of models that are executed at the aggregate level and whose output informs the next step in the sequence. Later improvements to the traditional four step process have included incorporating feedback loops between the steps (for example between route assignment, mode choice and trip distribution) (5) to create consistency in the variables used. The aggregate nature of the four step process is one of its major drawbacks divorcing it from choices that are made at the individual and household levels. The approach's focus on trips segmented by time-of-day and trip purposes has also meant that the daily time constraints faced by individual travelers as well as common travel patterns that involve trip chaining could not be considered.

Disaggregate approaches to travel demand analysis started to be used in the 1970s employing random utility models (6). These models assume a rational utility maximizing decision maker (7, 8) and the approach grounded travel decisions on a behavioral process given certain assumptions. Utility based choice models have found wide application in transportation studies which are filled with a variety of choice problems. Applications include, but are not limited to, the choice of mode, route, departure time, location, home and work. They have also entered the four step planning process to calculate mode shares between origins and destinations.

In contrast to real behavior the assumptions of random utility models are rather restrictive. Most individuals do not have the cognitive abilities to behave as these models assume. Human behavior is also not always consistent and transitive in its choices. The assumptions however allow mathematical models that are relatively easy to implement and that can account for many of the trends that are found in decision making in varied contexts. Researchers have documented decision making that is not captured well by these models, for example in the collection of works in (9). Other decision making frameworks such as bounded rationality (10) as well as prospect theory (11) are available though their application in transportation has been limited.

Newer generation of travel demand models have also found use for random utility models. These models, called activity-based models, found increasing attention since the 1980s. The works of Hagerstrand (12) on space-time constraints and Chapin (13) on activity patterns across time and space have been credited as the basis of activity-based models. These models differ from the trip-based approach of the four step process in that they explicitly consider the derived nature of travel demand. The models focus on activity participation and allocation of time within the confines of spatial and temporal constraints placed by long term location choices and work schedules. They are able to consider trip chaining and coordination which differs from the one origin-one destination formulation of the four step process. Bhat and Koppelman (14) as well as McNally and Rindt (15) summarize the key features of activity based models and the different approaches used in the development of these models. The focus of these models is on short term activity participation rather than long term choices (there are exceptions, for example Ben-Akiva nd Lerman (16) integrate an activity based model and a residential location model in nested choice framework).

2.3 Home and Work Matching

In matching home and work, the four step process takes a segmented approach. It treats homes and employment locations separately at the zonal level in terms of generation and attraction. Trips are generated based on residential zones whose composition is derived from household surveys. Trips attracted by zones depend on the amount of opportunities in a zone for a particular trip purpose. The second stage of the four step process, trip distribution, assigns the origin trips to destinations. The gravity model (17) is the most popular of the trip distribution models (others include the fratar growth factor models (18) and the intervening opportunities model (19)). Gravity models distribute trips using aggregate zonal measures of the origin and destination and a measure of transportation cost between the two.

These models are typically based on surveys of 1% of the population to develop models of destination choice. Inaccuracies arise for some very basic reasons, a region with, say, 1000 traffic analysis zones will have 1000 possible destinations, a large fraction of them are approximately isochronic from an origin. There are 1000x1000 possible Origin-Destination pairs, most of which have no trips, and a 1% sample cannot successfully map that set.

Consider as well how certain job finding methods may affect the destination of residents. If a significant amount of job finding in a zone occurs through neighbors for example such zones would produce more trips to particular destinations than would be expected by considering the separation between origins and destinations alone (and less to others). It is also plausible that work place contacts have some influence upon neighborhood choice leading to settlement patterns that reinforce such aggregation.

Concerns can also arise from how different search methods organize information for the searcher. It is possible that different types of search methods lead to different geographic outcomes at the individual level. Internet searches for example may lead to longer distances simply because the choice set generated from this method may be geographically wider than other methods. Referrals systematically exclude those with out an intermediary. Different job advertisement approaches can create an information divide that systematically excludes particular neighborhoods or groups.

While the use of random utility models in the choice problem can address some of the aggregation problems, it does not resolve the issue of the choice set generation. This latter problem can only be addressed by studying the search process that leads some people to the jobs that they have and excludes others from competing. In addition, job finding methods can go beyond choice set generation and make it highly likely that a particular position is taken. Consider for example a person looking for employment who had two competing opportunities to pursue. If one opportunity had an intermediary contact that affords a certain amount of influence and security in the job, preferences may be skewed in its favor. The analyst who is blind to this process would treat these opportunities differently from one that considers the contact's role explicitly.

Job search theory (20, 21) has been used by labor economists to explain the job search process and the behavior of searchers. The approach conceives of searchers that are faced with randomly arriving offers. In this approach unemployed workers receive offers which they choose to accept or reject with probabilities based on offer arrival rates, their reservation wage, and the offer. McCall (22) for example details the optimal strategy under different assumptions of what the searcher knows about the wage rate and employment durations. In the simplest model the optimal strategy is to continue searching as long as the marginal cost of searching (waiting for another offer) is lower than the expected gains from sampling one more offer. Several extensions of the basic model have been tested. Devine and Kiefer (23) present a review of the empirical work in this area. But many of these models do not have a spatial dimension.

Such an approach has also been criticized for ignoring the social dimension of job finding and treating individuals as if they are independent of all other relations around them. In his well known work, *Getting a Job*, Granovetter (24) explains "job finding behavior is more than a rational economic process - it is heavily embedded in other social processes that closely constrain and determine its course and results". Empirical studies have also illustrated that significant amount of job finding occurs through contacts. Summarizing four studies that occurred between 1951 to 1980, Montgomery (25) shows well over 50% of jobs in many sectors were found through friends and relatives. One of these, Granovetter's study in Newton, Massachusetts for example found that contacts were used for 56.1% of professional positions, 65.4% of managerial positions, and 43.5% of technical positions in his sample (24). In their study of job search and occupational segregation of women using data from Worcester, Massachusetts, Hanson and Pratt (26) also find very high use of contacts (53% and 43% respectively for those that grew up in the city and not).

Granovetter's study also illustrated some key properties of the contacts that were used. In many cases he found that weak ties were instrumental in matching employees to employers (27). The rationale is that these individuals tend to move in different circles from the job searcher and therefore are more likely to have information that the searcher does not have. People who have strong ties to the searcher are more likely to know the same information as the searcher, and therefore are not very good in relaying new and useful information.

Hanson and Pratt's study (26) also points to the need to pay closer attention to job search methods. In studying the occupational segregation of women, they find that men and women search for jobs differently and use different types of contacts for job finding with different outcomes. Women in women-dominated jobs were found to use personal and community based contacts more than their counterparts. They argue that this phenomenon, as well as inability to adjust their residence in response to a job change, and constraints that arise from domestic responsibilities, reinforce occupational sex segregation.

2.4 Work and Residence Choices

The connection between home and work has also been central to early models of urban structure. These models framed location choice in the context of a mono-centric city (28) where utility maximizing decision makers make location choices by trading off land costs with transportation costs to jobs to the city center (where all employment is located). But cities have always been much more complex than these models. Later models have considered decentralized jobs, incorporated neighborhood preferences as well as within household tradeoffs (29) in the selection of housing. Simpson (30) studies the job-work relationship using spatial job search from given residential locations. Later studies have also considered both job and residential choices from a search perspective that relates wages, place utility, and commuting costs (31, 32, 33, 34, 35, 36).

The urban demographic landscape suggests that there are components to home choice that are clearly important to the selection of one's home other than housing prices and transportation costs. There is for example considerable segregation along racial lines in the housing market in large urban areas in the US (37). Several rationales have been proposed for its existence including perceived social class difference (38), in-group preference (39), and prejudice (40, 41). Schelling (42) demonstrates a model where small differences in tolerance for other colors lead to segregation. Jargowsky (43) also found segregation along income lines after controlling for racial segregation. Neighborhood concentrations along age also appear to be present (44).

Disaggregate models of location choice have also been used to study residential choice. Examples include (45, 46, 47). The appeal of such models is in their ability to incorporate a variety of attributes that have to do with the house, neighborhood, the individual as well as such measures as accessibility in the random utility maximizing framework. The models have also been used to investigate different nested structures. Waddell's (46) model for example brings together workplace, residential mobility, tenure, and location choices. Abraham and Hunt (47) look at home, work and mode choices.

Studies have also shown that people do not minimize commute time in their selection of home and work (48, 49, 50). Guiliano and Small (50) list several reasons why this may be the case including the with-in household effects of multi-worker households, increasing importance of non-work trips and other housing and neighborhood attributes. Levinson (51), using metropolitan Washington data, investigates if recent movers have shorter commutes, and whether those that moved to new homes had longer commutes. His findings suggest that those who move, on average, maintain their commute durations. These findings indicate the complexity of how households try to balance competing interests.

One of the considerations that will be explored in chapter 5 is the role that access to one's close contacts plays in how far away one moves from their prior home after finding new employment. The Homophily (52) concept in social networks suggests that people and their social contacts are similar in many dimensions. The role social networks play in location choices then may have implications for some of the demographic concentrations seen in neighborhoods. Anecdotally, at least in immigrant communities, social contacts seem to play a reinforcing role in increasing their concentration.

2.5 Summary

Different approaches have been used to model how choices of home and work are made, and to study the commute outcome. The choice of home and work are each informed by one another, and are also affected by a wide variety of external factors such as job and neighborhood quality, home prices, as well as choices made by others. Each of these dimensions are evaluated in the context of what the decision maker knows making both job search and residential search an important area of study. In this study we focus mainly on the job search process and to a lesser degree on relocation decisions. The role of social contacts and other search methods in the choice of work and home are studied in chapters 3, 4 and 5. Chapter 6 develops and tests an agent based model of home-worker matching which generates choice sets using a search process. Later in chapter 7 we will also discuss the role played by social networks in social activity travel for which the literature will be reviewed in the chapter. The next four chapters study how the job search process and social networks in particular affect the job and residential choices of individuals.

Chapter 3

Contacts and Location Decisions

3.1 Introduction

Humans are social animals. We interact with one another, form different types of relationships, maintain ties with one another over time and space. We are continuously collecting information about each other, what we think of particular people, places, goods etc. A simple question such as "What did you do yesterday?" can garner a range of responses about neighborhood locations, schools, restaurants, and so on. To what extent these interactions inform our understanding of our environment depends on whom the information comes from, the type of relationship we have with them, how convincing they were, and whether the information gets reinforced through other channels. This process along with personal experience helps individuals gather, discard, reinforce and refine their perceptions and knowledge about their environment.

On a day to day basis, much of the information gathering is passive. However, when the need arises for a particular good or information, the take-off point for the search is likely to be these stored information that have been built up over time. During an active search, the searcher can return to the original source for in depth answers or may seek alternate sources to refine the search. For example, a person who has mentioned his experience with a particular school district can be asked in depth questions, or one who seems to be well connected to employers of interest in past discussions can be asked to pass on a recommendation. Alternatively the searcher can seek out similar information from other sources in taking future steps.

The roles that social networks and their structure play in a variety of individual and social activities has been a matter of much research. These studies span multiple fields including labor market studies (e.g. (24, 53, 54, 55)), crime and unemployment (e.g. (56)), health (e.g. (57, 58, 59)), child care (e.g. (60, 61)), inter-firm alliances (e.g. (62)) and others. More recently the role of social networks in transportation decisions has also received increasing attention (63, 64, 65, 66, 67) among others.

In this chapter we explore whether interaction among social contacts is a significant source of information on jobs and housing. Specifically we are interested in the role neighborhood and workplace networks play in work and home finding. Our purpose in focusing on the neighborhood and workplace contacts is driven in part by the implications it has in transportation planning applications.

The neighborhood and workplace are seen as spaces that bring people together and facilitate information sharing. In this sense our conception is similar to that of Feld (68) who points out that many social networks develop around a *focus*. The "focus" in his theory can be anything around which joint activities take place including places, people, work, etc. One of his basic propositions maintains that two individuals that are tied to the same focus are more likely to be tied to one another than two people not so related. Each individual can have many foci and different networks arising from their involvement in each, and can play different roles both within the focus and across foci. We will look at the workplace and the residential neighborhood as the foci around which social networks can develop and where information is passed among residents about work and among workers about residence locations.

It is clear how sharing a home or work location can lead to higher chances of influence. Two persons, A and B, are more likely to know one another if they work at the same location than two individuals randomly selected in the population. If A and B know one another and have further similarities in other dimensions, then it becomes more likely that they would share their experiences and the possibility for mutual influence grows. Similarly at the home neighborhood, people who live close to one another have higher chances of knowing one another, and are more likely to interact with and influence one another as compared to two people randomly selected in the population. The possibility for acquaintance and influence increases further if they are involved in similar other activities (for example a homeowners association, membership in a neighborhood club, or if they have children going to the same school).

The link between where people live and go to work has been a topic of much research in transportation planning. As indicated in chapters 1 and 2 trip distribution models try to match origins and destinations, often using aggregate zonal variables to estimate the level of interaction between zones by the number of travelers going from an origin zone to a destination zone for different purposes. At its basic, the gravity model distributes trips from origins to destinations in direct proportion to the "size" (or some measure of opportunity) of the origin and destination and in inverse proportion to the separation/cost between them. Explicit consideration of the job-finding or home-finding process within these aggregate models has not been made.

This chapter posits that co-location at the home or work location reinforces co-location in the other sphere as contacts in each sphere share information about their respective jobs and neighborhood. In the transportation context, this would mean that home-work location sharing (co-location) would be higher than what can be explained by travel time, neighborhood characteristics and demographic preferences. If the influence of contacts is significantly observed, one would expect that certain residential neighborhoods produce more workers for a given employment district than can be explained by travel time, and opportunities at the destination alone.

There are of course other mechanisms in which peoples' home and work locations can coincide. Some of the selection criteria that individuals use in selecting home or work locations would certainly include travel cost between home and work. Thus two people living in close proximity and having a short commute time, may work together without influencing one another. In addition home location decisions can be driven by people wanting to be close to those that are demographically more like them leading to the selection of some neighborhoods more than others. Observed levels of homogeneity in neighborhood racial composition, and economic class suggest that a household's decisions are impacted by others even when those "others" may not be personally known. Racial (37), income (43) as well as age (44) segregation are witnessed to different degrees. The analysis below seeks to investigate whether co-location among those that are spatially close to one another is significant even within such communities.

There is ample research in the field of sociology on the role played by social contacts in work finding. The economics literature on the other hand had widely adopted a search theoretic approach to the job search problem (see (23) for a review). Summarizing four studies that occurred between 1951 to 1980 Montgomery (25) shows well over 50% of jobs in many sectors were found through friends and relatives. Granovetter's (27, 24) work also identified which contacts were important in relaying information to find a job. He found that weak social ties, rather than strong ones with close family members and friends, were instrumental in relaying information that makes job finding possible. The rationale is that these individuals tend to move around in different circles from the job searcher and therefore are more likely to have information that the job seeker and their close contacts do not. People that have strong ties to the searcher are more likely to know the same information as the searcher, and therefore are not very useful in relaying new information (in contrast, in China, Bian (69) finds strong ties to be more effective in getting jobs where influence was essential). The existence of a consiedarable number of (weak) social ties at the neighborhood level is shown in (70). Here we ask whether these contacts are instrumental in work finding.

One of the biggest challenges in teasing out such relationship based outcomes at a large scale is the availability of data. In the next section we will discuss the data and methods we use to investigate the home and work relationships. That will be followed by an analysis of co-location patterns in eight areas in the Minneapolis-St. Paul metropolitan region. Finally, we investigate the relationship between comparatively high levels of colocation and different block level demographic variables and some conclusions are presented.

3.2 Data

The data for this study comes from the Longitudinal Employer-Household Dynamics (LEHD) program of the U.S. Census Bureau which compiles data from federal and state sources (71). Here we use the prototype OD matrix for 2002 for the state of Minnesota. The OD data requires the linkage of residence and worker data that are gathered from the federal and state levels respectively. Description of the OD data is give in (72) and much of the description of the data below borrows from this description.

Residence location data for the LEHD is gathered from the Census Bureau's Statistical Administrative Records System (STARS) database. STARS includes data compiled from records including federal tax forms, Medicare, HUD public assistance, Selective Service registration and so on. The data is geocoded and locations for about 10% of the workers that are not geocoded are imputed.

Data on the work locations comes from States. In this case the ES-202 report from State of Minnesota's Covered Employment and Wages program is used. The data is reported by employers whose employment is covered under Unemployment Insurance. The Minnesota data is estimated to cover 97% of non-farm employment in Minnesota (73).

The worker-employer link in the LEHD data is derived from Unemployment Insurance wage reports supplied by the State of Minnesota. Part of the strength of the Minnesota data is that work locations are reported at the establishment level within an employer allowing more accurate O-D matching. Some states reports may show the head office but not identify the establishment at which a particular worker is employed requiring additional models to assign work locations.

For confidentiality, the 2002 LEHD OD prototype reported trips only if the origin had at least five workers living in it, and if the trip makers had three or more destination blocks. Later versions of the LEHD have used other methods to preserve confidentiality.

We have limited our analysis to origins and destinations within the seven-county metropolitan area of the Twin Cities (Minneapolis-St. Paul).[1] In the following sections we will investigate the extent of co-location at home and work between residents of several blocks and study how the degree of co-location varies across the demographic make up of the Census-blocks.[2]

For the first part of the analysis, eight areas, each constituting several Census-blocks are selected. Four of these were selected in the city of Edina and four in the city of Brooklyn Park. The number of Census-blocks in the selected areas ranged between 11 to 23. Each group is selected to have approximately 500 workers. The second part of the analysis will look at how co-location at work is distributed across the metropolitan area. The extent of co-location is analyzed against the demographic makeup of the Census-blocks utilizing demographic data from the U.S. decennial Census. The analysis will include all metro area Census-blocks where the origin had at least two workers originating from it to any metro area work block.

3.3 Methodology

We are interested in testing (i) whether work Census-block sharing among people who share a home Census-block is higher than what we would expected by travel and land use considerations and (ii) which Census-blocks exhibit relatively higher home-work sharing. The first of these questions would indicate the presence of a coordination mechanisms

[1] The seven counties are Anoka, Carver, Dakota, Hennepin, Ramsey, Scott, and Washington counties.

[2] A Census-block is the smallest geographic area for which the Census Bureau presents data. Blocks are grouped together to form block groups.

among people in their choice of home and work locations. This would support the neighborhood and work place information flow hypothesis we have presented above. The second part of the analysis would explain what type of neighborhoods exhibit it strongly relative to others.

The first part of the analysis willa borrow methods from Social Network Analysis. We measure the extent of home-work co-location by building adjacency matrices for residents of the areas under consideration at home and at work. A network adjacency matrix is a matrix representation of the relations between the members of a network. Because of the level of detail in the LEHD data set, we define a relationship as sharing a Census-block for residence or sharing Census-block as a work destination. The home and work relationships are depicted in two adjacency matrices, one for the residence end (H^m) and one for the work place (W^m). For a selected area that has N workers as residents, the adjacency matrices for the H^m and W^m matrices will be NXN in dimension, where each row and column represents one individual. Cell $[i, j]$ of the H^m matrix will have a value 1 if person i and person j share a home location or 0 otherwise. The same element in the W^m matrix will have a value of 1 if i and j work together and 0 otherwise. Both H^m and W^m are symmetric matrices. The diagonal elements are ignored as they do not have any meaning. For an area that has N residents there are $N(N-1)/2$ possible relationships.

Having defined the home and work matrices, our study focuses on the relationship between these matrices. Specifically we ask what the degree of association between these two matrices is when both matrices are defined over the same subset of individuals. We are also interested in running statistical tests on the level of association between the matrices. We employ three measures of association between the home and work matrices: Pearson correlation, simple matching and Jaccard coefficient. Simple matching and the Jaccard coefficients are calculated as described below:

Simple Matching: The simple matching coefficient measures to what extent the two matrices at the home and work block level are similar entry by entry. There are

$n(n-1)/2$ relationships defined in each matrix. This measure tells us what proportion of these relationships are equal to one another in the home and work adjacency matrices. For instance a 0.6 value means 60 percent of the relationships defined at home and work are the same (60% of relationships are absent or present at both). The measure is calculated as follows:

$$S_M = \frac{C}{C + D} \tag{3.1}$$

where C is the count of matched pairs (0-0 or 1-1) and D is the count of un-matched pairs (0-1 or 1-0) between the H^m and W^m matrices.

Jaccard Coefficient: The Jaccard coefficient looks at what proportion of possible ties are matched between the home and work location relationships. This measure excludes all values that are matched 0s in the home and work adjacency matrices.

$$J = \frac{C_{11}}{C_{11} + D} \tag{3.2}$$

where C_{11} is the count of matched 1-1 pairs and D is the count of unmatched pairs (0-1 or 1-0) between the H^m and W^m matrices.

One of the challenges in applying statistical tests to relationship/network data is that observations are not independent of one another. Each entry of the matrix reports the presence/absence of a relationship between two actors, thus observations on relationships involving the same actor are not independent of one another. This makes hypotheses tests that assume independence between observations less useful. Social scientists have been dealing with such data in other contexts. One solution that has been used to address this problem is using Quadratic Assignment Procedure (QAP)(74).

QAP is a non parametric test that depends on repeated permutation of one of the network matrices and building a distribution of the test statistic of association under the null hypotheses. The permutation preserves the structure of the network while it relabels the vertices of the network. In our case for instance, if we were permuting the work matrix W^m, we would be exchanging relationships among the individuals in consideration, while maintaining the size of the clusters. From a trip distribution stand point, one can think of this as reassigning the destination blocks of the agents in the network while maintaining employment levels at each of the destination blocks. Figure 3.1 illustrates what the process does in the context of our analysis. The relationships at the home location remain unchanged throughout the procedure. Under successive permutations, the number of people employed at each of the destination blocks under consideration also remains unchanged. The difference is that at each iteration the employees that fill the positions are now pulled from different origin blocks. For example in Figure 3.1 the destinations have 3, 3, ,3 and 1 employees respectively under the observed network as well as under permutations. However, different individuals are fill these positions under the permutations.

It is important to note that the QAP test, as well as the H^m and W^m matrices, do not explicitly control for origins and destinations. The method is generic enough to be applied to any type of network. The only information contained in the matrices is which groups of individuals are related and the structure of the network that develops (e.g. how many ties are there? how many cliques etc.). Under permutation, the structure of the network is unaffected. For instance the total number of ties, the number cliques as well as the size of each clique is not affected. The QAP test simply exchanges the relationships in the W^m matrix and calculates the test statistic of interest against the H^m matrix. After several iterations, the distribution of the test statistic under permutation is compared to the original test statistic. The percentage of test statistic under permutation that are as great or greater than the observed test statistic serves as the p-value of the test.

To answer whether work Census-block sharing is higher among people who share a home Census-block, we start by selecting several areas and build the H^m and W^m relationship matrices for workers in living in the selected area. Our selection strategy is for each area to include a number of Census-blocks that are adjacent to one another and to analyze each group separately. As will be illustrated in the next section, there are certain advantages of selecting Census-blocks that are close to one another. First blocks that are close to one another tend to be more socio-demographically homogenous than a randomly selected set of blocks. Our intention is to illustrate that even among a demographically homogenous group, people who are closer to one another tend to work together than those slightly farther from them. Second distances to different land uses around them are relatively similar. Third, by selecting home blocks that are adjacent to one another we are more or less maintaining the overall origin-destination distance distribution. If one were to map the destination locations under permutation, the home to work distance of any one individual can change significantly from the original depending on whose position they are now assigned in the network. However, because the selected residential locations are very close to one another and the distance between homes is small, the overall distribution of distance is not affected significantly.

In permuting the adjacency matrix we start by generating a permutation vector. A simple way to think about this vector, and one which works with our context of reassigning destinations, is that its k^{th} element of the vector designates which position individual k in the original matrix would take. Consider the simple adjacency matrix shown below which shows the work-colocation between five individuals along with the permutation vector and the adjacency matrix permuted format. Under permutation, the first person is now assigned the position previously held by person 2 and will have two ties. Because the other persons are also reassigned, the relationship is not necessarily with those person 2 had relationships with. If the home locations of persons 1-5 is the same, and they are now simply reassigned to the work locations of the element in the permutation vector, the overall distribution of distances will remain the same.

$$\begin{bmatrix} - & 0 & 0 & 1 & 0 \\ 0 & - & 1 & 0 & 1 \\ 0 & 1 & - & 0 & 0 \\ 1 & 0 & 0 & - & 0 \\ 0 & 1 & 0 & 0 & - \end{bmatrix} \qquad \begin{pmatrix} 2 & 1 & 5 & 3 & 4 \end{pmatrix} \qquad \begin{bmatrix} - & 0 & 1 & 1 & 0 \\ 0 & - & 0 & 0 & 1 \\ 1 & 0 & - & 0 & 0 \\ 1 & 0 & 0 & - & 0 \\ 0 & 1 & 0 & 0 & - \end{bmatrix}$$

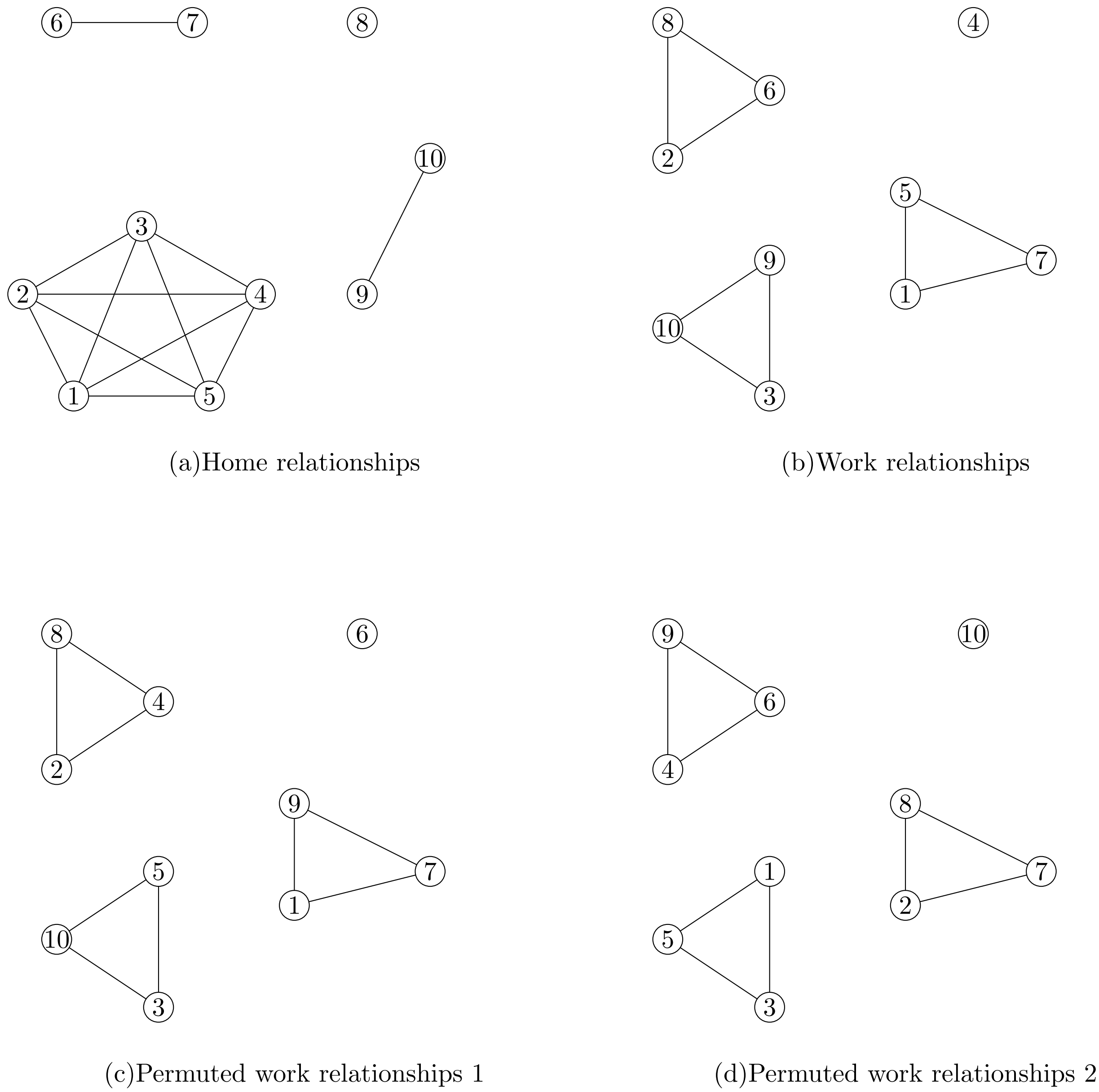
This point can be illustrated using one of the areas selected for the analysis in the next section. The area Brooklyn Park 2 in table 3.1 includes 495 workers originating from 19 Census-blocks and destined to 263 Census-blocks. The resident's home coordinate is designated by the coordinates of the centroid of their home Census-block and their work coordinates are also designated by the centroid of the destination. Calculating the new home to work distance under 1000 different permutations and comparing the distance distribution to the actual distance distance distribution using a two sided t-test, no evidence of difference between the distributions was detected with p-values ranging from 0.865 to 0.970.

Thus under the quadratic assignment procedure and the sampling strategy we have adopted (i) home locations remain unchanged (ii) employment levels at destinations remain unchanged and (iii) the overall distance distribution also remains relatively the same.

3.4 Analysis

3.4.1 Measuring Association Between Home and Work Co-location

The QAP analysis described above is applied to eight areas in the cities of Edina and Brooklyn Park, Minnesota, part of the Twin Cities Metropolitan region. Four areas are randomly selected within each city. Each of the selected areas had several blocks within it and approximately 500 workers destined to different blocks in the metropolitan



(a)Home relationships (b)Work relationships

(c)Permuted work relationships 1 (d)Permuted work relationships 2

Figure 3.1: Sample Home and Work Networks

area. Detailed results for one group of blocks in Edina will be presented and we will summarize the results for the remaining groups of Census-blocks in table 3.1.

The first group of blocks in Edina (Edina 1) contains fifteen Census-blocks from which 495 workers originate. The workers are destined to 235 Census-blocks for work. Under permutation, people are assigned new co-location relationships at the work location. The area is also demographically relatively homogeneous as compared to the city of Edina. Figure 3.2 shows the distribution of racial makeup, average family size, and median age in the Census-blocks of the city of Edina and the first group of blocks.

Table 3.1 shows the results of the QAP analysis using all three measures discussed above. In each case, while the magnitude of the measures are low, they exist to a degree that cannot be easily replicated by exchanging the work locations of the individuals. The last column in the table in the column serves as the measure of p-value of the test. In 1000 permutations, no measure of simple matching, Jaccard coefficient or correlation as large as that in the observed network was observed.

The results for the three other groups of blocks in Edina and the four groups of blocks in Brooklyn Park are also similar (see Table 3.1). The association measures under permutation are less than what is observed in the observed arrangement.

By selecting Census-blocks that are close to one another we have attempted to control for distance impacts as illustrated earlier. The permutation process itself ensures that the total number of persons working together is kept the same by retaining the structure of the network. Only the identities (and hence where they are attracted from) of the individuals that are working together is changed. The results suggest that there are possible mechanisms that lead to co-location patterns that are significantly different from what are possible arrangements of employment.

A shortcoming of this type of analysis is that not all jobs are exchangeable. Individuals could in reality also be restricted in their choices of job location by the type of employment that is available. So the distribution on which the null hypothesis is based upon may not be tenable in reality. Alternately, there are certainly many more

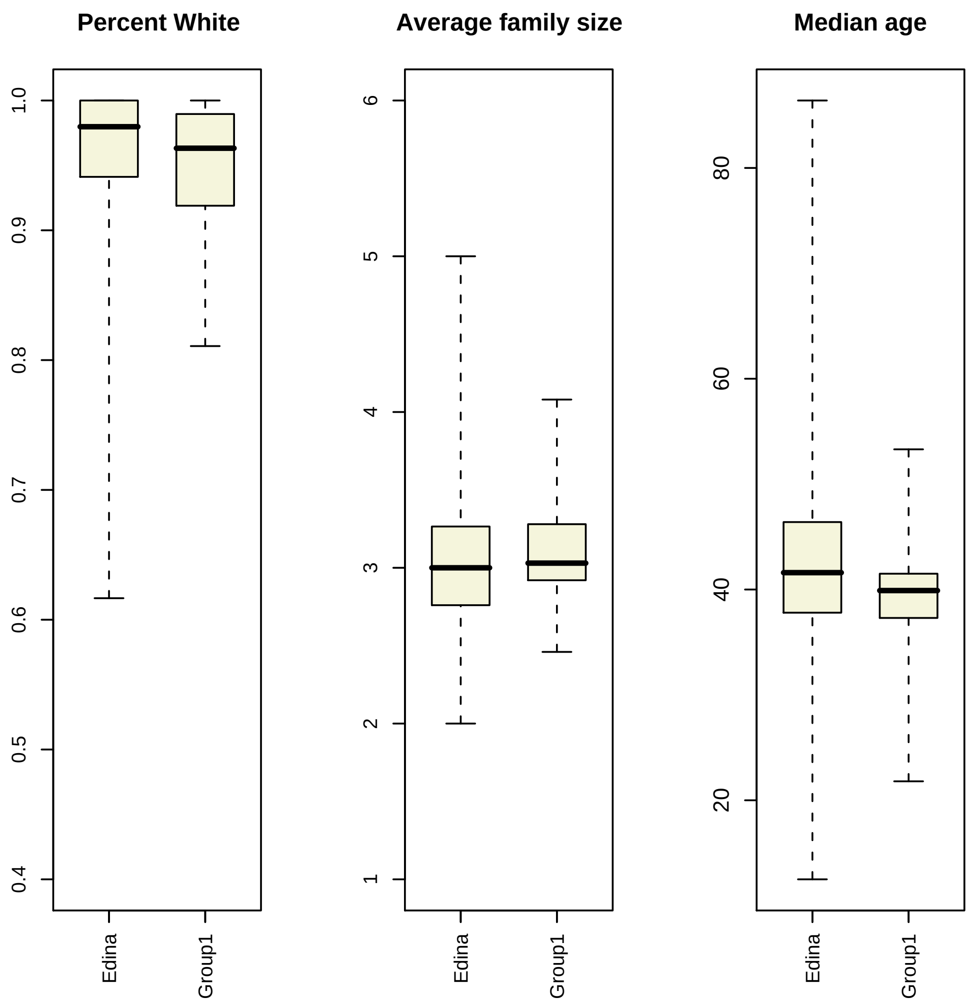


Figure 3.2: Boxplots of the distribution of demographic variables in selected Edina blocks. The box shows the interquartile range, while the whiskers extend to the range of the the observed values. The median is shown by the bold line within the box.

Table 3.1: Quadratic Assignment Procedure Results

Group	Number of origin blocks	Number of destination blocks	Number of workers	Association measure	Observed	% greater (p-value)
Edina 1	15	235	495	J	0.03	0.00
				S	0.91	0.00
				C	0.08	0.00
Edina 2	21	256	504	J	0.03	0.00
				S	0.93	0.00
				C	0.09	0.00
Edina 3	11	223	481	J	0.03	0.00
				S	0.93	0.00
				C	0.05	0.00
Edina 4	23	241	511	J	0.03	0.00
				S	0.93	0.00
				C	0.10	0.00
Brooklyn Park 1	19	263	495	J	0.03	0.00
				S	0.92	0.00
				C	0.10	0.00
Brooklyn Park 2	22	263	494	J	0.03	0.00
				S	0.93	0.00
				C	0.12	0.00
Brooklyn Park 3	13	307	606	J	0.01	0.00
				S	0.58	0.00
				C	0.03	0.00
Brooklyn Park 4	17	251	447	J	0.03	0.00
				S	0.92	0.00
				C	0.11	0.00

locations in the metropolitan area where fitting employment may be found suggesting home-work co-location at the block level may have other mechanisms behind it. Another concern is that intra-household information sharing might also be at play in the extent of co-location that is observed.

It is instructive however to study the relationship between the degree of co-location and the socio-demographic characteristics of the each of the Census-blocks in the metropolitan area. For instance if locations that have more renters than homeowners show lower co-location, this would be in line with our hypothesis of social network influence. This is because there is little reason why intra-household effects would be different between renters and owners other things equal. However the degree to which people know their neighbors would be expected to be higher for homeowners than for transient renters. The next section examines the relationship between aggregate socio-demographic characteristics of residential blocks based on the 2000 U.S. census and the level of co-location each block exhibits calculated using the LEHD data.

3.4.2 Home-Work Sharing across Census-blocks

This section will look at how home-work co-location varies across the Census-blocks in the metropolitan area. Data for this portion of the analysis comes from the U.S. Census Bureaus decennial national census. The variables in our model used below come from the 100-percent characteristics form that is asked of every person and housing unit in the country and released aggregated at the Census-block level.

The unit of analysis for this portion of the study is the Census-block unit. As such the H^m matrix for all blocks contains only 1s and has no variation across blocks except for its size. To compare which Census-blocks have relatively higher incidence of people working together, we will use the density of the W^m matrix for the residents of each block.

The density of a network measures what proportion of possible ties are realized. Its value can range between 0 and 1. For a Census-block with N workers, the density of the work relationship is the count of ties (1s) in the upper triangle of the W^m matrix divided by $n(n-1)/2$. If everyone in the home block works at the same destination, the density of the W^m network is equal to 1. If on the other hand everyone in the Census-block goes to their own unique Census-block for work, then the density is 0 since no ties are present in the work matrix. Coincidentally, because the entries of the H^m matrix are all ones, the simple matching, as well as the Jaccard coefficient calculated for a single block are also equal to the density of the work block.

Table 3.2: Origin Block Characteristics

Variable	Description	Category	Percentage
R	Race	White	95.80%
		Black	2.50%
		Asian	1.03%
		Other	0.66%
A	Age	< 30	21.42%
		30-40	48.42%
		40-50	23.18%
		50-65	5.75%
		>65	1.24%
H	Percentage of one person households	$> 75\%$	1.14%
		50 - 75%	4.47%
		25 - 50%	26.52%
		<25%	67.86%
O	Percentage of owner occupied dwellings	>85%	69.90%
		50-85%	16.23%
		25-50%	6.03%
		<25%	7.84%
Total Blocks Used		32494	

A logit model is used to analyze the relationship between density and block characteristics. To control for the opportunities that are available from each residence area and the ease of accessing them, gravity based accessibility measures as estimated in (75) for the Twin Cities are used. The gravity based measures use the LEHD number of job reported for each of the blocks aggregated to the TAZ level and uses the reciprocal of the square of the travel time between TAZs for impedance (see (75) for more details). In addition to accessibility measures, racial composition as well as variables that control for demographic characteristics of each block are used. The proposed model is as follows:

$$log(\frac{\rho_b}{1-\rho_b}) = \beta_0 + \beta_1 Ac_b + \beta_2 R_b + \beta_3 A_b + \beta_4 H_b + \beta_5 O_b + \beta_6 F_b$$

where:

ρ: The tie density of the W^m matrix

Ac_b: the gravity based accessibility measure of the TAZ that the block is in (/1000)

R_b: The majority race in the block

A_b: the median age in the block

H_b: the percentage of one person households in the block

O_b: the percentage of owner occupied households in the block

F_b: the average family size in a block

The distribution of these area characteristics in the study area is given in Table 3.2. In fitting the model, we have controlled for the number of workers originating from the block. The density measure goes down at a much faster rate for each additional individual added to the network since one additional individual means $n - 1$ possible ties in the network. Initial fitting of the model showed over-dispersion as evidenced by the ratio of the deviance and the degrees of freedom. A scale was estimated by the square root of the the deviance divided by the degrees of freedom. The scale does not affect the estimates but rescales the covariance matrix. The final model is as shown in 3.3.

Blocks that have relatively higher accessibility measures exhibit higher incidences of working together. In part this may be due to the ease of job access that individuals in such blocks have close to them. As the number of opportunities in a particular block grows the possibility of working at that particular location for any given individuals also grows. After controlling for employment accessibility, interesting relationships between block level demographic variables and home-work co-location.

Although the majority of home blocks are predominantly White, a fraction of the blocks (about 4%) have populations that are predominantly Black, Asian, or "Other" (which includes Native American, Hispanic, or mixed communities). Compared to blocks that are predominantly White, blocks where a majority of the population is Black, Asian, or Other have higher tie densities at the work location. Especially predominantly Asian blocks exhibit larger co-location patterns. Blocks with Black or Other racial groups as the majority also tend to have higher co-location than whites (p-value = 0.05).

The model also illustrates that blocks where multi-person households constitute more than 75% of households have higher work-place density than all other categories (p-value=0.00). No significant difference was detected between the other categories and the base category of greater than 75% single-person households. The finding suggests that location decisions in multi-person households maybe significantly different that in single-person households. This may be because of within-household effects, where people who live together also share a work location, or because individuals with multi-person households have better social networks within their neighborhoods and workplaces that lead to information transfer about jobs/houses.

As the median age in a block group increases, so does the possibility that people who live in that block also share a work block. The estimates indicate that odds of co-location are significantly higher for each age group as compared to the youngest of blocks. With age and experience individuals may better be able to exploit their networks at the neighborhood in getting employment, and may also want to locate closer to contacts that are much like them. They may also be ready to put more weight on neighborhood quality recommendations by others, and less likely to try out a new neighborhood on their own.

Table 3.3: Logit Estimate of Workplace Tie Density by Census-block

Parameter	Description	Categories	Estimate	S.E.	chi-square	p-value
Intercept			-2.953	0.04	6346.14	0.00**
N	Number of	25 - 49	-0.666	0.01	4820.49	0.00**
	workers	50 - 99	-1.19	0.01	14601.8	0.00**
	in block	100 - 200	-1.684	0.01	27088.6	0.00**
		> 200	-2.147	0.01	47076.8	0.00**
Ac_b	Accessibility		0.012	0.00	199.09	0.00**
R_b	Majority	Black	0.033	0.02	3.85	0.05*
	race	Asian	0.199	0.03	38.19	0.00**
	in block	Other	0.079	0.04	3.95	0.05*
A_b	Median age	30 - 39	0.054	0.01	51.6	0.00**
	in block	40 - 49	0.091	0.01	81.62	0.00**
		50 - 65	0.199	0.02	137.21	0.00**
		> 65	0.134	0.03	15.93	0.00**
H_b	% of one	50 - 74 %	0.003	0.03	0.01	0.92
	person	25 - 49 %	0.027	0.03	1.09	0.30
	households	< 25 %	0.102	0.03	14.64	0.00**
O_b	% of owner	50 - 85 %	-0.029	0.01	12.14	0.00**
	occupied	25 - 49 %	-0.05	0.01	21.57	0.00**
	households	< 25 %	-0.019	0.01	2.55	0.11
F_b	Family size		0.016	0.01	4.76	0.03**
Scale			2.42			
Fit Statistics						
		(Intercept + N term) only			Model	
Scaled Deviance			35939.61		35244.27	
Logliklihood			-774142.76		-772794.76	
Number of observations			32494			
Significance: ** ≤ 0.05		*< 0.1				

Finally, blocks that have a large number of owner-occupied dwellings have significantly higher incidence of people working together. As the proportion of owner-occupied dwellings goes down in a block, the probability that someone will work with another person in their residence block also goes down. This is possibly because homeowners, who are likely to reside in their residences longer, form better social networks with those around them as opposed to renters who may relocate much more easily and see themselves as only temporarily in the area. Curiously blocks with fewer than 25% owner occupied households don't have a statistically significant lower incidence (p-val = 0.11). Blocks that have larger average family sizes also show larger incidence of home-work co-location.

Taken together, these results suggest that neighborhoods with older, predominantly multi-person, owner-occupied households tend to have a higher incidence of co-location at home and work than other neighborhoods. Co-location as measured by the workplace network density is higher in blocks that are occupied by mature and settled households.

Blocks that are predominantly Asian, Black or Other also display higher incidence of working together. In part this may be due to relatively segregated low-income job opportunities, but coupled with the QAP results earlier, it may also be indicative of communities having mechanisms in which co-location is maintained at a higher degree than predominantly White neighborhoods. Such patterns may in fact be pronounced in areas where new immigrants have settled where they are likely to depend on contacts to find a place of work.

3.5 Conclusion

This chapter hypothesizes that social networks formed around the home with neighbors or with co-workers are instrumental in finding work and choosing a residential area. We test this hypotheses using OD data at the Census-block level for the metropolitan area of the Minneapolis-St. Paul. Quadratic assignment procedure is applied to eight areas in the Twin Cities that each contained several Census-blocks by defining home and work co-location networks as living in the same block and working in the same block. The findings suggest the observed co-location patterns are not easily replicated when people's work locations were exchanged with one another while keeping their home locations the same. That analysis is followed by a look at how network density as measured by the work place network for residents of each Census-block in the Twin Cities varies with different demographic characteristics. The findings suggest that co-location is higher in blocks that are occupied by mature households (older, multi-person, homeowner dominated households).

The social network paradigm proposed here posits that neighbors and co-workers play an important role in the choice of work and home by passing information about particular opportunities/homes or in general giving guidance on neighborhood quality. Location decisions that arise from these information flows could result in people living and working in closer proximity to one another with more frequency than would be expected otherwise. The results from the QAP analysis support such a hypothesis. Coupled with information about the spatial separation between work and home, understanding and explicitly including such mechanisms of location choice would theoretically improve our ability to predict the matching of origins and destinations. Such findings also give us hope for exploring innovative solutions to encourage car-pooling among people who live and work close to one another, and in job-matching for people who are under or unemployed. Future work should utilize data that has more details and more specific information on relationships than the LEHD origin destination data can provide. Gathering relationship data of this scope is rather difficult and costly. However access to individual level variables could at least help further exploration by redefining relationships not only by Census-blocks but by demographic classes as well.

Chapter 4

Job Finding Path

4.1 Introduction

Job finding is generally preceded by an active search period to find the best matching position for the searcher. This search process has changed over the last two decades due to changes in technology. How these changes have affected the commute, tenure and relocation for workers is the subject of this and the next chapter. Over the last decade and a half, the availability of the internet has changed the way many people search for employment. Because of it, job opportunities that would have been difficult to know about from outside of a labor market can now be accessed much more easily. Though relocation and transportation costs limit the size of the labor market from expanding to the state or national level, for those that would have been just outside of the geographic limits of the labor market, the internet makes new opportunities possible. From a transportation perspective this could mean longer commutes, or increased rates of relocation.

This chapter looks at how information on jobs is found, and who searches and succeeds in finding employment using a particular search method. The changes in technology and the changes in successful job search method over time are also studied.

Chapter 5 looks into how changes in the way information is found affect home and work locations, and the related consequences on relocation and tenure. Hypotheses are presented and tested about the complex relocation decisions by households after finding work and how employment finding methods directly or indirectly influence these decisions.

Information from contacts, newspapers, recruiters, and the internet can be utilized to different degrees by different searchers in finding employment. Depending on the type of labor market that an employer is located in and the employment opportunities it has, its advertising strategies will differ. For instance employers with low skilled job opportunities may choose to avoid recruiters, or rely on community bulletins and local newspapers. On the other hand, the internet may be a more suitable medium to recruit people who would have to use a computer in an office environment, for technical people, or to recruit for positions from a wider set of backgrounds. Depending on the circumstance, employers can also use a mix of these of these recruitment venues.

The search path that a job seeker decides to follow impacts what opportunities are available to them. The number of opportunities, their locations, and the likelihood of successful placement depends on which methods are used. For instance a local newspaper would mostly have local opportunities, recruiters may also be confined to particular employers or industries. On the other hand the internet can provide information from a much larger set of employers covering a wider geographic area, but the plethora of information can make success and finding a good match dependent on the proficiency of the searcher.

The increased access to the internet presents significant advantages both to searchers and employers. It reduces the search cost and expands the set of possible opportunities. A searcher can narrow alternatives based on job description, or more specific criteria, as well as on geography, limiting searches to those opportunities that are near their home. Once an individual has access to the web, changing the geographic scale of search or other attributes has minimal costs allowing them to access information that would otherwise have been costly by any other method.

The opportunities that the internet provides also provide new challenges. The ease of access to the internet means that the same information is available to a wider pool of people, which can make the competition for a particular position much stronger than it would have been had the labor market been confined by the reach of traditional search tools. Alternately, the expansion of the set of opportunities at very little search cost might lead one to finding more jobs at distant locations that otherwise would not have been considered, requiring longer commutes, or the need for relocation.

To look into the complex responses that arise as a result of the changes in the search process and its impacts on home and work locations, we undertake a survey of residents in the Twin Cities area in two phases. The survey focused on work finding, relocation, the role of ICT and social contacts, as well as the social travel that respondents participated in. In the following section we will discuss the survey and data collection and follow that by an analysis of work finding methods. In Chapter 5 we will look at relocation decisions that follow job finding. The social travel data will be the topic of Chapter 7.

4.2 Survey and Data

A two phase web based survey was administered to gather data on job finding, home finding, the meetings that people participate and the social and technology networks that help them in the process. Respondents were recruited through mailed postcards. Recruitment postcards were sent to eight zip code areas in the Twin Cities to 5000 people in each of the two phases. The areas selected are shown in figure 4.1. The areas were chosen to have an economic and racial mix of respondents, as well as a city and suburban mix in the respondent pool. Reminder postcards were sent a week following the original mailing.

The survey was internet based and invited respondents were asked to login to the survey with a unique code placed on the mailed postcard. The survey participant had to be a working adult in the household. Respondents were asked to not complete the survey if they did not satisfy this criteria. The survey also offered a $5.00 coffee card to participants who completed the survey as well as a chance to be included in a drawing for an iPod Touch for one randomly selected respondent in each phase.

On first mailing 192 and 205 cards were returned due to wrong addresses from each phase. Overall there were 268 and 297 respondents in phase 1 and 2 respectively (5.88% of postcards that reached their destination). The response rate for the survey was low and perhaps could have been increased by repeated solicitation to the respondents. In addition, because the questions went into the details of people's contacts and daily schedules, privacy concerns may have led some to drop out or skip questions that they were not willing to answer. Another possible reason for the low response might be availability of a computer and access to the internet in lower income areas.

The postcard mailer is shown in Appendix A.1. Screenshots from the survey are included in Appendix A.2. The decision to go with postcard mailings and to have an online survey were factors that were mainly influenced by cost.

The distribution of demographic variables among the respondents and that for the Minneapolis - St. Paul Metropolitan Statistical Area (MSA) from the American Community Survey (ACS) for 2006-2008 is given in Table 4.1. Overall the sample shows bias towards women, and more highly educated individuals as compared to the demography of the metropolitan population.

Broadly speaking, the survey focused on four areas. The first section dealt with the experience of the respondent during their last job search. Respondents were asked how they found their job, including whether contacts were used, and if so, details on the contact. The second section dealt with their residence, including when they moved and what their reasons for moving were, the third section dealt with the respondent's social network and what their weekly social meeting looks like. The survey ends with questions about the respondent's commute and demographics.

Table 4.1: Summary of Survey Subjects

Variable	Group	Survey	Minneapolis-St. Paul MSA
Gender	Male	39.8%	49.7%
	Female	60.2%	50.3%
Age	Median	37	36.3
Household	Renter	22.5%	25.8%
	Owner	77.4%	74.2%
Education (MSA data for those 25 and older)	Less than high school	0.4%	7.4%
	High school	16.6%	46.7%
	Associates degree	14.1%	8.9%
	Bachelor's degree	45.7%	25.1%
	Grad/Professional degree	23.1%	11.9%
Household Income	Mean	$ 76,550	$ 84,527
	Median	$ 68,000	$ 66,281
Race	White	90.3%	86.2%
	Black	3.4%	7.4%
	American Indian	0.2%	1.2%
	Asian	3.2%	5.4%
	Other	3.0%	2%

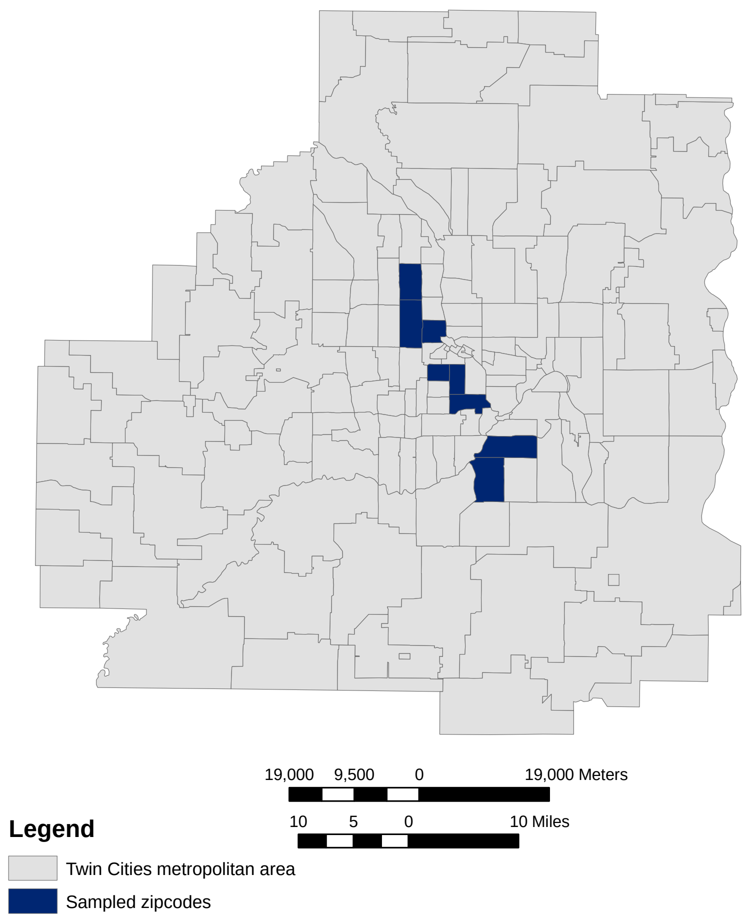


Figure 4.1: Zip codes of residents to whom recruitment postcards were sent in the Twin Cities metropolitan Area

4.3 Job Finding and Changes in Technology

Respondents were asked to specify how they found their current job. In this study, job finding paths are classified into four groups by the information source the searcher used to find employment. The categories are formal, internet, newspaper, and contacts. The formal category includes the use of recruiters, employment agencies, using job fairs, temp to hire agencies, and application mailing. contacts can be friends, families, colleagues, etc.

By far, the use of contacts is the primary method of job finding in our sample. Excluding the self-employed, contacts make up over 40% of the reported job finding path. Figure 4.2 shows the share of each medium in our respondent pool, categorized by when the respondent started their current work. In each time category, contacts have held their share steady even as technological changes have taken place. On the other hand, the share of employment that people find using newspapers and formal searches has declined as the internet has picked up a significant proportion of the job finding market, though some of the rapid rise observed here maybe because this survey, because of how it was administered, looks at a sample that has access to the internet. The technology however has not been able to make a dent into the share of employment that is found through contacts over time even among this group.

While the share of jobs found through the internet is increasing, this number is much smaller when compared to the proportion of people who report they would use the internet as their primary job search tool if they were searching now. Of the respondents that are not currently self-employed, 66.3% responded that the internet would be their primary tool for job finding (N=475). In contrast only 22.1% of those who started their current job since 1995 (N=417) report using the internet to find their current employment. Of those that found their current job from January 2005 and on (N=207), the share that found it via the internet is 30.9%, which is less than half the 74.6% in this group that report would use the internet as their primary search tool. The

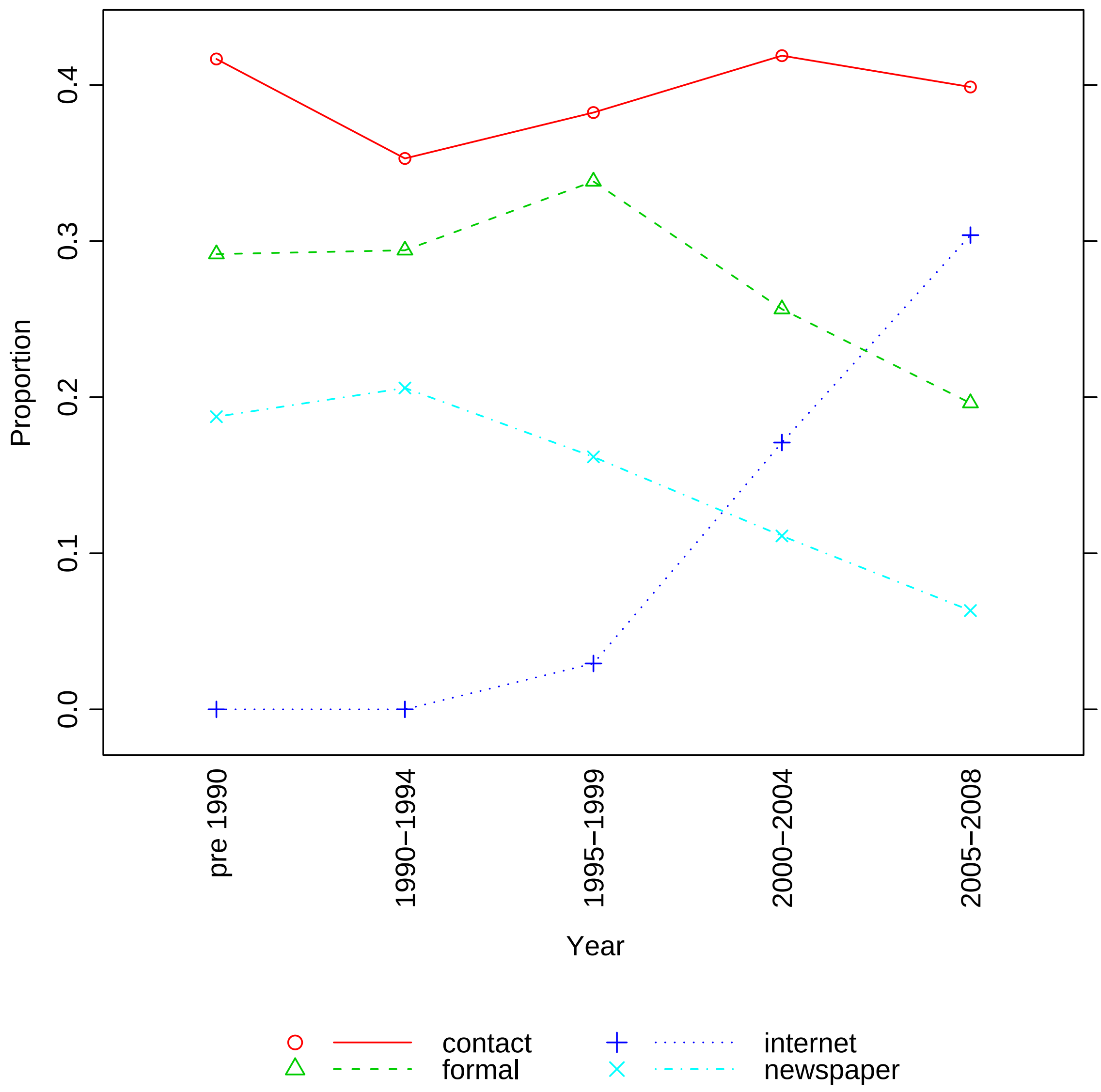


Figure 4.2: Job finding strategy proportion by year

comparable proportions for using contacts are 18.3%, 42.7% and 43.4% for those that would use contacts primarily, used contacts since 1995, and used contacts from 2005 and on respectively. Table 4.2 presents these proportions for each search path.

These numbers demonstrate that because of its low cost and ease of access, the internet dominates as the tool of choice for job searches. However it is rather inefficient (at least as compared to contacts) in leading to successful employment. Feldman and Klass (76) highlight some of the challenges of using the internet for employment including the web-skills of the searcher, content of announcements, recruiting practices, and lack of followup among others.

When it comes to contacts, over twice the number of people that would use it as a primary search method found employment that way. The personal recommendation of a contact known both by the employer and the job seeker can give assurances to both searcher and the employer and lead more successfully to employment. Of course, use of the internet has other advantages that the job seeker can exploit in their employment regardless of whether their search through the internet was successful. They are able to learn more about the market in which they are competing, the going wage for their experience level, and other information relating to successfully getting employment. In this way the internet both competes with (most successfully with newspapers) and complements the other job search paths.

Table 4.2: Primary job search method vs. Job finding

	primary job search	Proportion of people that found their job		
	(if searching today)	before 1995	1995 and later	2005 and later
contact	18.3	40.2	42.6	43.5
formal	9.3	34.1	24.5	18.4
internet	66.3	0.0	22.1	30.9
newspaper	4.4	22.0	9.6	5.8
other	1.7	3.7	1.20	1.4
N^*	475	82	417	207

* Excludes self employed individuals and non responses

Recognizing that changes in job finding have taken place, the following sections will explore if these changes have implications on the location of job found, and on residential relocation decisions afterwards. To accomplish this, the differences among individuals in effectively using one search path over the other towards successful employment is studied first. In chapter 5 the sample is divided into individuals who found their current work while at their current residence, and those that have since relocated to a new home. The two groups will be used to compare the distance outcome of job search, and the relocation decision that follows job finding.

4.4 Social Networks, Technology and Job Finding

The search path followed by each individual depends on the resources they have at their disposal. It is likely that the easiest starting point is the least costly option at the time. The decision also depends on the person's characteristics at the time of search. While there maybe a personal preference for one search method or another, there is little reason for a searcher to not employ all paths given they are available. While different paths may bring different types of opportunities, acceptance of an offer will depend less on path than the contents of the offer. The exception here might be when contacts are involved, in which case the path could play a deciding factor between alternatives where the offer attributes are reasonably close.

Using a multinomial logit model we explore which variables are important for success of one path over another in our sample. The dependent alternatives are the use of contacts, internet, formal means, or newspaper. These are modeled as depending on the person's characteristics, the size of their social network and their network's geographic proximity to their residence, how long ago the search took place, and whether or not they were employed at the time of their search.

The multinomial choice model using the probability of using contacts as the base level is specified as follows:

$$\eta_{ic} = \beta_{0i} + \beta_{1i}G + \beta_{2i}E + \beta_{3i}I_h + \beta_{4i}A_{js} + \beta_{5i}Y_j + \beta_{6i}E_m + \beta_{7i}C_s + \beta_{8i}C_{p3}$$

where

$\eta_{ic} = log(\frac{\pi_i}{\pi_c})$: The log odds of using search method i relative to using contacts, where i = 1 for formal, 2 for internet, and 3 for newspapers.

G: Gender (1 = Male)

E: Education

I_h: Household income

A_j: Age at the time of starting current job

Y_j: How long ago was the job search done (years)?

E_m: Was the person employed at the time?

C_s: Number of close contacts (those with whom respondent interacts with twice a month or more, and don't live in the same house as respondent).

C_{p3}: What proportion of these contacts live within 3 miles of your current residence?

Some of the variables may have changed for the subjects since their days of finding employment. This is especially true for subjects who have been employed at their current job for a long time or those that have relocated. The estimated model is reported in table 4.3.

The base alternative against which the odds are estimated is the likelihood of using contacts. Gender, household income, and age at the time of employment do not describe the successful job path process for the sample. The successful job search path depends on education, time elapsed since search (technology change), whether a person was employed at the time of search , and in some cases the size and proximity of their social network.

Table 4.3: Multinomial model of job finding path

		formal			internet			newspaper		
Variable		est.	s.e.	p-val	est.	s.e.	p-val	est.	s.e.	p-val
(Intercept)		-1.07	0.78	0.17	-0.30	0.87	0.72	-2.72	1.24	0.03*
G	Male	-0.41	0.27	0.13	-0.46	0.31	0.14	-0.19	0.35	0.59
E	Associate	0.18	0.49	0.70	0.70	0.60	0.25	1.11	0.57	0.05*
	Bachelors	0.76	0.38	0.05*	1.31	0.50	0.01*	0.62	0.51	0.23
	Graduate	1.11	0.43	0.01*	1.02	0.56	0.07	0.77	0.59	0.19
I_h	30-49.9K	0.12	0.72	0.86	1.07	0.81	0.19	0.94	1.17	0.42
	50-74.9K	-0.28	0.71	0.69	0.45	0.81	0.58	1.12	1.13	0.32
	75-124.9K	-0.22	0.70	0.75	0.54	0.81	0.51	0.70	1.14	0.54
	$\geq$ 125K	-0.76	0.79	0.33	-0.25	0.98	0.80	-0.19	1.28	0.88
A_{js}	30-39	0.11	0.30	0.72	-0.07	0.37	0.85	-0.29	0.42	0.49
	40-49	0.04	0.40	0.92	-0.49	0.50	0.32	0.41	0.47	0.39
	$\geq$50	0.29	0.52	0.58	-0.08	0.54	0.88	-0.09	0.74	0.91
Y_j		0.04	0.02	0.02*	-0.23	0.05	0.00**	0.06	0.02	0.01*
E_m	Yes	-0.54	0.27	0.04*	-0.47	0.31	0.13	-0.47	0.35	0.18
C_s	6-15	0.90	0.40	0.03*	-0.34	0.42	0.42	0.14	0.48	0.77
	16-50	0.53	0.44	0.23	-0.51	0.46	0.27	-0.43	0.56	0.44
	$\geq$50	0.25	0.83	0.76	-0.31	0.87	0.72	-0.21	0.98	0.83
C_{p3}	1-10%	-0.78	0.55	0.15	-0.40	0.63	0.53	-0.10	0.76	0.90
	10-25%	-0.41	0.34	0.23	-0.31	0.39	0.43	-0.09	0.46	0.84
	25-49%	-0.28	0.36	0.44	-0.18	0.41	0.67	0.12	0.49	0.81
	$\geq$50%	-1.69	0.83	0.04*	-0.56	0.71	0.43	-0.09	0.76	0.90

Model statistics			
Obs	415	LR $\chi^2(51)$	113.48
$pseudo-R^2$	0.116	$Prob > \chi^2$	0.000

Significance: * $\leq$ 0.05 **$<$ 0.01

All other things equal, Bachelors degree holders have the highest odds of successful job placement using the internet, followed by using formal means. Those with graduate degrees have the highest odds of success by using for formal means, followed by the internet, and those with an Associate degree have the highest odds of using the newspaper as their path to a job. The odds of using the internet successfully is highest for Bachelor's degree holders. More specialized positions that require more than a Bachelor's degree are best served by recruiters. The market for such positions is also likely to be narrower, hence the higher success rate by using a specialized searcher in particular industries. The model also suggests that for sectors that employ people with educational levels less than a Bachelor's degree, the best recruitment path is the newspapers. Levels of access to the internet may be depressed in this education class, searching skills online may not be as developed, and as a result employers might be more inclined to use the traditional advertisement strategies they have been using in the past.

Whether or not the person was employed while searching for their job is also important in the choice process. All things equal, a person who is employed is more likely to get their next job through a contact than through formal means (p-val=0.04), the estimated signs for *internet* and *newspaper* searched also indicated that contacts work better than both methods when a person is employed. This can be a result of people who are employed having more contacts who are also working in their field and therefore can access those contacts for jobs. In addition, referrers may be more comfortable recommending a contact who is already employed and has active experience.

As expected the time to employment is also important as it accounts for the advantages of each path at different times. The higher the number of years elapsed since finding their current job, the less likely the person used the internet to find employment. The likelihood of employment using formal means and the newspaper increases as the time to when the employment decision was made gets longer.

Both the size of the searchers social network, measured as the number of people they keep in touch with at least twice a month that do not live in the same house as them, and proximity of that social network, measured as the proportion of contacts who live in a 3 mile radius of the respondent, were included in the model. The model estimates suggest that size of social network (C_s), as measured here, is not an important indicator of job search path except of those with a smaller social circle (6-15). This group was more likely to use formal means than contacts. In all other cases the size of the social network does not influence the search path.

When the proportion of close contacts that live in a 3 mile radius exceeds 50%, that person is much more likely to use contacts rather than formal means for job finding. In all other cases, the findings do not show statistically significant relationships between geographic proximity to a large number of contacts and the successful job search path.

4.5 Summary

This chapter looked at the job search search process and how it has changed over time. Within the sample that was considered, job finding through contacts has held a relatively steady proportion of jobs found. Newspapers are losing ground to the internet. As for the internet, while it is cited by many as their primary tool for job search, its potential for successful employment among primary users is found to be less than that of contacts.

The analysis highlights the following points. After controlling for time effects and all other things equal, education level and employment at the time of search are important indicators of what path is followed. Both of these variables have directions as expected. The social network variables, size (C_s) and the percentage of close contacts in a 3 mile radius (C_{p3}) show a mixed pattern. These variables matter in two cases: (1) when the social network size of the respondent is small, formal means are more likely to have been used than contacts, and (2) when the proportion of contacts in a 3 mile radius of the respondent's home exceeds 50%, use of contacts is more likely than formal means. In other cases, the social network variables have no detectable impact on the successful path the subjects followed.

Chapter 5

Job Changing, Home Relocation and Commuting

5.1 Introduction

This chapter looks at the changes in home-to-work distance and travel time after finding new employment by comparing how it varies across respondents and the search path they used to find work. Different factors can influence the home-to-work distance job seekers would consider reasonable when trying to find work. Household composition, employment status at the time of search, demographics, current living conditions can all have varying degrees of influence.

Renters and home owners likely have different tolerances for new commute distances. Household responsibilities can also affect what is readily accepted. Longer commutes could mean less time to spend at home, or can affect other activities that have fixed time. For example, having to pick up a child from a childcare facility by a certain time can easily require the exclusion of certain locations as possible work sites without changing childcare arrangement. In addition, people who are attached to their homes or neighborhood may be reluctant to accept very long commutes when comparable employment alternatives are present at shorter commutes. Others in the same group may be willing to accept longer commutes while staying in their homes if other employment alternatives are not available to them.

In addition to such household, demographic, and economic constraints, the search path to finding employment may also play a role in the geographic location of employment. Differences in search methods are hypothesized to influence location because of the way in which information is gathered by each search medium. For instance one can compare the breadth of the search geography when using the internet with that of using contacts, local newspapers, or doing walk-in applications.

Certainly, not all jobs that are found by searching the internet are farther out, and not all opportunities that are farther out are accepted. Ultimately the searcher makes the decision on what opportunities to pursue and accept. However, that certain opportunities can only be accessed (or be better accessed) by one search medium and not others given the geographic location of the searcher alters the choice set from which opportunities are pursued. It is this distinction in home-to-work distance that may arise from employing different search paths that we wish to uncover in the first part of this chapter.

The second part of this chapter, deals with decisions that are made after a job searcher has found employment. In particular we wish to understand the effect the job search path (either directly or indirectly) has on subsequent relocation decisions such as how soon they relocated, their new commute, and how far from their previous residence they move. Differences may arise because the home to work distance outcomes from some search paths maybe longer than others. They may also be a result of the implied job security because of the search medium (for example when using contacts). Relocation decisions are seldom made solely based on commute considerations. Factors such as neighborhood quality, other activity locations, schools and so on also play important roles.

In addition, factors such as the number of contacts the relocating household has in close proximity can also influence the specifics of how far away one relocates from their previous location. People who want to stay close to their local contacts may not move as far away as others from their previous location. Consequently they may trade closeness to these contacts by foregoing a reduction in their commute.

5.2 Employment Search Path and Commute Outcomes

To uncover the relationship between search path and commute outcomes, the current home-to-work distance and travel time are modeled as a function of whether the respondent owns or rents their current residence, the method of job finding, the age of the person when taking the job, and the number of years they had spent in their residence at the time of taking the job.

This model is applied to individuals who have not yet relocated after finding their current work. This would mean individuals who have relocated because their commute was onerous for example would be excluded. If indeed particular search paths led to longer commutes that resulted in quicker relocation, it would make this model conservative in its estimation. Dummy variables are also used to control for different suburban home locations. The proposed model is as follows:

$$E[D_{hw}] = \beta_0+\beta_1 R_c+\beta_2 J_f+\beta_3 J_i+\beta_4 J_n+\beta_5 I+\beta_6 A_j+\beta_7 E+\beta_8 H+\beta_9 Y_{hj}+\beta_{10} L_{NW}+\beta_{11} L_{SE}$$

$$E[T_{hw}] = \beta_0+\beta_1 R_c+\beta_2 J_f+\beta_3 J_i+\beta_4 J_n+\beta_5 I+\beta_6 A_j+\beta_7 E+\beta_8 H+\beta_9 Y_{hj}+\beta_{10} L_{NW}+\beta_{11} L_{SE}$$

where:

D_{hw} : Home-to-work distance (dependent variable for model 5.1)

T_{hw} : Home-to-work travel time (dependent variable for model 5.2)

R_c : Do you currently rent your residence? (yes=1)

J_f : Job found through formal means

J_i : Job found through the Internet

J_n : Job found through newspaper advertisements

A_j : Age at the time of taking job

Y_{hj} : Number of years at current residence at the time of taking the job

L_{NW} : Dummy variable for home location in the north west suburbs of the Twin Cities

L_{SE} : Dummy variable for home location in the south/south east suburbs of the Twin Cities

The estimated models are given in Tables 5.1 and 5.2.

In the distance model (Table 5.1), the variables of household income, age at the time of taking the job and household size are not significant and do not explain the variability in the data. As hypothesized, among those who have not yet relocated after finding work, renters live farther from the employment location than do homeowners. This is likely because renters can relocate easily to new locations, and can adjust their travel time at the time of relocation.

Job seekers who used the internet and newspapers to find work both have longer home-to-work distances than do those that used formal means and contacts (p=.064 and p=.055 respectively). The mean home-to-work distance for internet users is higher by 2.4 miles and for those using newspapers, it is higher by 3.4 miles. This is likely due to the wider geographic scope of information that is gathered by the internet and newspaper. While recruiters can specialize in one geographic area, or be told to look for opportunities in a particular neighborhood, identifying particular neighborhoods for a job (except in high job-density areas) may be strategically not very fruitful for job searchers using the internet or newspapers. This is because at an almost zero additional search cost, more opportunities that can be good matches can be located. Even if the searcher wanted to geographically limit searches the required effort to sift through information could possibly bring new opportunities to the fore. The possibility that using formal means was more suited to one type of area over the other was tested using the data (for example jobs at the CBD and using recruiters etc.) but no association was found between search path and distance of the employment location from the CBD.

The other variable that was significant was the dummy for the northwest suburb. Respondents living in this area reported higher home-to-work distance than respondents in the City of Minneapolis or in the southeast suburbs. The reason is likely related to the thinner job density in these locations relative to the center and southern parts of the metro area. Home tenure before finding the new work location has the expected negative sign, indicating those that have lived in their homes (and neighborhood) longer opted for closer work opportunities ($p=0.107$).

Looking at the travel time model (Table 5.2), though the signs and tendencies exhibited by the model estimates are similar to those in the distance model, many of the statistical significance are absent. For example internet and newspaper users still have positive relationship with travel time ($p=0.256$ & $p=0.122$ respectively), renters show a higher travel time than owners ($p=0.156$) and those in the northwestern suburbs report higher travel times ($p=0.139$). While distance and travel time are correlated, travel time depends on variables such as capacity and demand on the routes between home and work, and in some cases places that are farther can be reached much faster than places that are geographically closer due to differences in demand and capacity.

Overall, the distance model suggests that job finding paths have unique characteristics that would lead to different home-to-work distances. The use of contacts and formal means such as recruiters leads to locations that are on average closer to the searcher than do using the internet or newspaper. On the other hand, based on our data this distinction in distance is not reflected in the travel time data though the trends are similar.

Table 5.1: Home-to-work distance (miles) after finding new work

Variable		Estimate	Error	t value	$Pr > \|t\|$
(Intercept)		4.605	2.673	1.720	0.087*
R_c	Renter?	3.371	1.233	2.730	0.007**
J_i	Job internet	2.399	1.288	1.860	0.064*
J_c	Job contact	-0.037	1.209	-0.030	0.976
J_n	Job newspaper	3.278	1.698	1.930	0.055*
I	Houshold income	-0.052	0.110	-0.480	0.634
A_j	Age job taken	0.008	0.052	0.160	0.874
E	College degree?	1.291	0.969	1.330	0.185
H	Household size	0.288	0.330	0.870	0.384
Y_{hj}	Home tenure	-0.114	0.070	-1.620	0.107
L_{NW}	Northwest suburb	2.967	1.190	2.490	0.014**
L_{SE}	Southeast suburb	1.153	1.148	1.000	0.317
Analysis of variance					
Source	Df	Sum of squares	Mean square	F value	$Pr > F$
Model	11	1014.59	92.24	2.99	0.0012
Error	163	5029.62	30.86		
R^2		.168			
Significance *** 0.01	** 0.05	* 0.1			

The differences in distance along with other household demographic and economic constraints can influence relocation decisions or the location decisions once the decision to relocate has been made. To study the possible relationships between job finding and decisions of residence afterwards (stay/move, stay for how long, and if moving to where?) the next section will focus on the survey participants that have relocated their residence since finding their current work.

Table 5.2: Home-to-work travel time (minutes) after finding new work

Variable		Estimate	Error	t value	$Pr > \|t\|$
(Intercept)		12.283	3.464	3.55	0.001***
R_c	Renter?	2.286	1.605	1.42	0.156
J_i	Job internet	1.901	1.666	1.14	0.256
J_c	Job contact	-0.251	1.556	-0.16	0.872
J_n	Job newspaper	3.449	2.218	1.56	0.122
I	Houshold income	-0.099	0.141	-0.7	0.485
A_j	Age job taken	0.029	0.067	0.44	0.659
E	College degree?	1.311	1.254	1.05	0.297
H	Household size	0.049	0.430	0.11	0.909
Y_{hj}	Home tenure	-0.175	0.090	-1.95	0.053**
L_{NW}	Northwest suburb	2.283	1.536	1.49	0.139
L_{SE}	Southeast suburb	-0.969	1.475	-0.66	0.512
Analysis of variance					
Source	Df	Sum of squares	Mean square	F value	$Pr > F$
Model	11	953.65	86.70	1.7	0.077
Error	161	8201.93	50.94		
R^2		.104			
Significance *** 0.01		** 0.05	* 0.1		

5.3 Commute Outcomes of Relocation After Finding Employment

Residential relocation decisions are much more deliberate than most other location decisions. These decisions can be motivated by a range of issues that have to do with changes in household structure, economic changes in the household, changes in the neighborhood etc. In addition to these factors, Clark and Withers (77) do find that job changes can also serve as a trigger to housing relocation decisions. They find the effect of a job change is especially strong for single renters and weaker in two-worker households. Clark and Burt (78) also note a higher probability to relocate when the home to work distance is long. In this section relocation outcomes after finding work are studied, along with different attributes of the relocating household that inform the relocation decisions. In addition to the usual demographic and commute related variables, we also study the role that social contacts play in informing the location choice.

Selection of a new location upon relocation often has to balance competing needs of the household. Commute is one part of the consideration, but it is not the only one. For example Giuliano and Small (50) find that the actual commute distribution is greater than what would be expected had people made commute-minimizing location choices. According to a 2004 mobility report by the Census Bureau (79), most people reported relocating due to housing related reasons (51%) or family related reasons (26%). Work related reason were reported as primary by 16% of respondents. A significant portion of these reported moving to a better home/apartment (20%), moving to own a house (10%), or a new job or transfer (9%). The survey, which allowed for only one response per individual, did not consider secondary or tertiary roles played by commute distance/time in narrowing down a location among possible alternatives. There are often many locations that can satisfy only one location consideration. In such cases, secondary reasons can play important roles to refine the location choice.

In the web based survey administered for this study (see Chapter 4), the primary, secondary and tertiary relocation reasons cited among all respondents are given in table 5.3. The primary reasons most often cited by the respondents are cost of the unit and affordability of the area followed by closeness to work and closeness to family and friends. Aggregated together home and neighborhood related reasons make up a majority of the reasons cited. "Being close to work" is cited frequently as one of the top three reasons for relocation with 36.7% of respondents whose previous home was in the metropolitan area of the Twin Cities selecting it. Figure 5.1 shows the previous-home-to-work and current home-to-work distances. It is clear that many maintain or reduce their commute distance upon relocation. The figure also shows that most of those that cited commute as a reason for relocating did reduce their home-to-work distance from what it would have been had they not relocated.

Evidence that many households maintain their commute upon moving is also presented in a case study of the housing changes of employees at a Southern California firm (80). The authors find that trip lengths of the employees did not increase substantially over a period of six years. Looking at how commuting distances change, Clark et al. (81) find that households that have high commutes to begin with shorten their commutes, and that women were more likely to shorten their commutes after a move than men. The stability of travel times over a long period of time is observed as the employment landscape in major metropolitan areas has been changing by suburbanizing jobs and housing. This stability has been explained as arising from rational location decisions both by firms and individuals to keep travel time constant (82). Levinson (83) has also posited that the increasing accessibility that arises from jobs that have followed suburbanizing homes has helped create this stability.

Relocation after finding employment can be an immediate or long term consideration. How soon relocation takes place can depend on the circumstances of the relocators' residence (rent/own, location etc.) and lifestyle and household characteristics at the time of employment as well as the characteristics of the new employment affect this decision. For instance a renter who found employment farther from their rental unit may find it easier to relocate to accommodate the new commute than a homeowner. Larger households, or dual earner households may find it more difficult to relocate. A person planning to buy a house next may find the costs of immediate relocation not worth any of the benefits relocation provides. Those who like their neighborhood, or have numerous local friends may opt to not relocate or relocate closer to their previous location while achieving the other goals of relocation. Age, income, household size and so on which influence the lifestyle of the decision makers can also have impacts on relocation considerations.

The last section showed the relationship between commute distance and job finding methods. Similarly, job finding methods can also play a role in relocation decisions because of the distance outcomes that they lead to. For example the longer distances

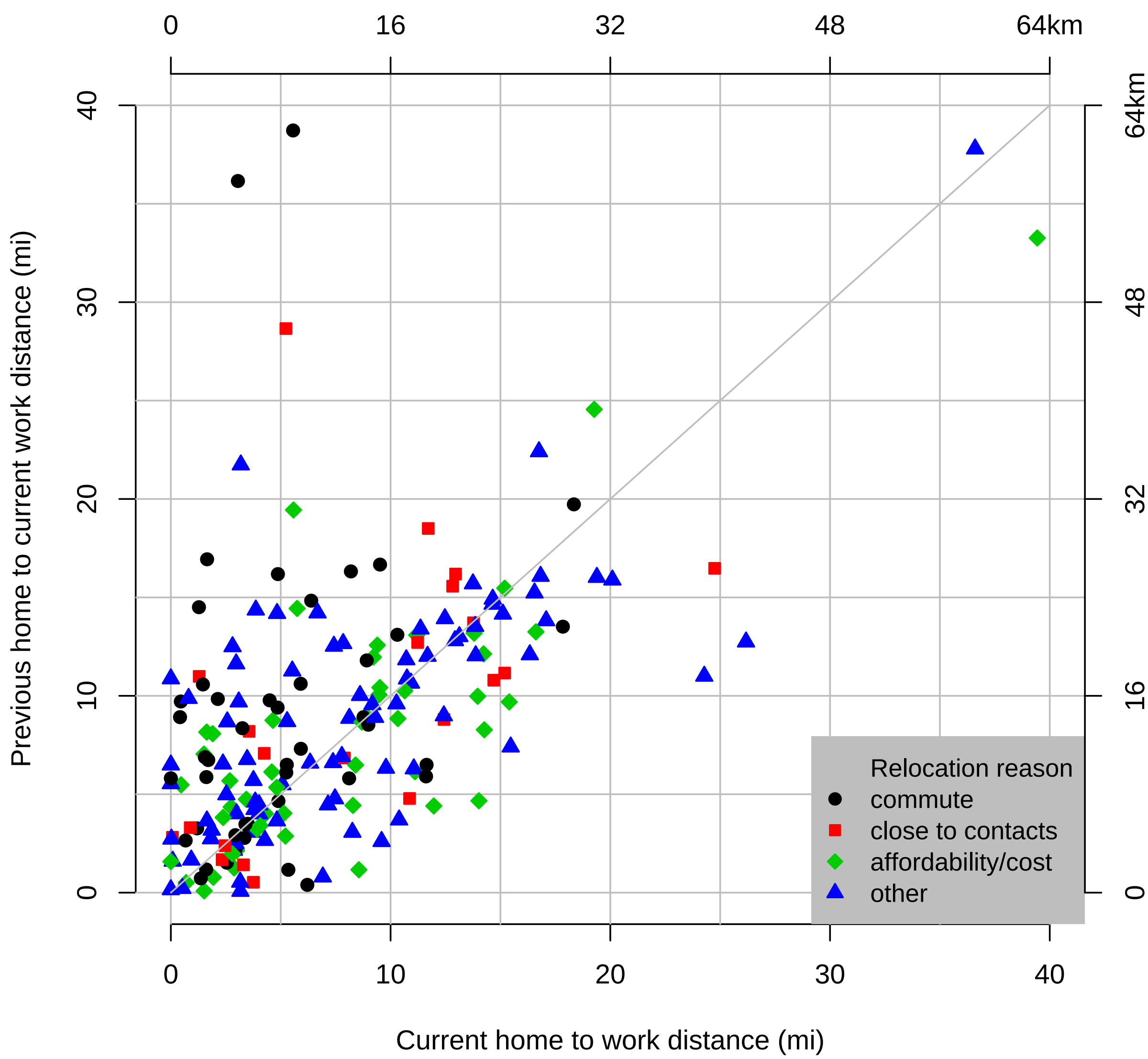


Figure 5.1: Distance between home and work before and after relocation for individuals who have relocated since finding their current work.

Table 5.3: Top three reasons for relocation among those whose previous home was in the Twin Cities metropolitan area (percentages)

	Reason 1	Reason 2	Reason 3
Cost of living/affordability	27.89	21.09	13.83
Close to work	17.01	12.93	8.16
Close to family/friends	10.43	12.47	7.94
Bike friendly area	0.23	1.36	2.49
Close to transit	1.13	2.49	2.27
Close to the city	14.74	14.06	12.7
Close to church	0.91	2.04	1.13
Close to open spaces	2.95	6.58	8.62
Larger lot size	1.59	1.81	3.17
Away from the city	0.68	0.23	0.91
Residence unit features	7.94	5.44	6.35
Safety	1.81	3.17	3.63
Kid friendly neighborhood	1.36	3.4	5.67
Good school district	3.17	2.04	2.72
Investment value of home	2.27	3.4	6.35
Other	2.04	1.81	1.36
Unreported	3.85	5.67	12.7
Count		441	

of internet and newspaper found jobs may lead to relocation to adjust the commute. Another reason that job finding methods may be important is due to their employment outcome. For instance some research has shown employees who found their jobs through contacts to be paid more at least initially (84, 85), and that they also have longer tenures (85). The sense of security in the position that may arise from the job finding path may encourage individuals to make lifestyle changes more quickly than they otherwise would.

Among the competing considerations that relocating households have, this section hypothesizes that individuals with larger social contacts in their neighborhood are less likely to move, or when they move they are more likely to move shorter distances away from where they were as compared to those that have fewer contacts in close proximity. Alternately as well individuals that have a large circle of close contacts around the metropolitan area are expected to relocate more freely.

5.4 Analysis

In this section, we uncover relationships between job finding, tenure before relocation, new commute and how far away people relocate from their previous location using variables reported from the survey discussed above. The influence of job finding methods, social contacts, household and personal variables and the interdependence between how long after job finding the person relocates, the new locations distance from the previous home, and the new commute are explicitly considered. The relationship between these variables can be studied using path analysis.

Path analysis has its origins in biology in the work of Sewall Wright (86, 87, 88, 89). Wright first used the method in linking the degree to which heredity and environment affect the color of guinea-pigs' offsprings (86). The method has often been called causal modeling, however, as Denis and Legerski (90) point out the case for causality has to lie outside of the statistical modeling technique.

Wright (91) describes path analysis as:

> "...a way of dealing with interrelated variables. It is based on the construction of qualitative diagram in which every included variable, measured or hypothetical, is represented (by arrows) either as *completely* determined by certain others (which may be represented as similarly determined) or as an *ultimate* factor."

The method is one where a hypothesized set of relationships that are dependent on one another can be tested. Path models employ both standardized and absolute (measured) variables in estimation. For the standardized estimates, each of the variables is adjusted so that its mean is zero and its standard deviation is equal to one. The standardized estimates of the path model give how many standard deviations the endogenous variable moves in response to a change in one standard deviation of the exogenous variable when all other variables are held constant. The regression coefficients, estimated from the observed variables, measure the contribution of each of the independent variables on the dependent variables.

Miller (92) summarizes the assumptions behind path models as follows:

- change in one variable is always a linear function in the change of another variable.
- there is no reciprocal causation.
- one must be able to prioritize the ordering of effects (tease out the primary effect from the indirect effect).
- the disturbances of the dependent variables are uncorrelated
- the usual assumptions in regression analysis are met (independence, homoscedasticity, etc.)

The hypothesized relationships between individual characteristics, job search, tenure at home, commuting distance, and different outcomes of the relocation decision is shown in figure 5.2. This relationship is imposed a priori based on the assumptions described in the proceeding paragraphs. Weights for the paths were estimated using the CALIS procedure of SAS software (93). Some paths were dropped during the analysis when found to be unimportant in explaining the hypothesized relationship. The final estimated model is shown in figure 5.3.

The assumptions behind the relationships in the path model are as follows. Relocation decisions after finding new employment are hypothesized to take time after finding work. This time is expected to be influenced by the persons' living arrangement, how they found their job, their age, what kind of move they aim to make, as well as their commute to the new work location. Younger individuals, as well as renters are expected to relocate faster. Individuals who aim to rent next are also expected to move sooner than those who aim to purchase their next residence. In addition, the longer their commute to their new employment, the quicker individuals are expected to relocate.

Job finding methods are also expected to have an impact on tenure after finding new employment. If the job was found through a contact, relocation is expected to occur sooner because of the implied confidence in the security of the new job. Individuals who found their job through the use of internet and newspaper are also expected to relocate sooner relative to those using formal means because of the longer distance outcomes of these methods.

In choosing their new residential location, individuals with smaller households are expected to be able to lower their commute than those with larger households who have to balance competing commute and location requirements. Those with larger incomes are expected to be motivated by other considerations such as larger homes, lot sizes, and amenities whose selection may take them farther from their employment site.

Individuals whose commutes become longer when finding new employment are expected to lower or maintain their previous home-to-work distance upon relocation. In addition, those individuals who relocate sooner are expected to lower their commute than those that stay at their current location under the new commute. In this arrangement, the commute right after relocation is expected to impact the new home-to-work distance directly, and indirectly through their tenure at their previous location.

Another consideration in relocation is also how far away from their current neighborhood a household relocates. Naturally the longer they have lived in the neighborhood, the more they know about it relative to other areas and the more attached they could be to it. How far away relocation occurs in this case is expected to be negatively impacted by how long after finding work, the relocation takes place.

In addition, the number of contacts a person has in their neighborhood can negatively influence how far away they relocate if closeness to these contacts is important to them. Alternately if an individual has a large number of contacts spread across the metropolitan area, it could mean that they have opportunities to relocate at locations that are farther from their current neighborhood while maintaining closeness to a desirable number of their contacts. The number of contacts a person has and the percentage of contacts in a 3 mile radius after relocation are used as indicator variables to how many local and total contacts the respondents had at their previous location.

The path model shown here encapsulates decisions taken over a long period of time. Job finding is the earliest event, and relocation is the latest event. These are separated by the tenure at the previous location after finding the current job. The age at which the current job was found and the years spent at the previous home add up to make the age at relocation. The new home-to-work distance and the previous home-to-current-home distance are outcomes of the latest decision.

In light of these time differences it is essential to establish which variables are from the time of the decision and which are not. Household size, household income, and household vehicles are from the time of the survey, and should be taken as indicator variables of lifestyle at the time of the decision. Just over 54% of the relocations considered here have occurred since January of 2004, and a further 20% since 2000. The number of contacts (C_s) and the percentage of contacts within three miles of home (C_{p3}) are variables reported as of the time of the survey, and these should be considered as indicator variables of how many total close contacts a person has and how many of those are in close proximity to them.

Many of the hypothesized relationships hold while a few are found having the opposite direction from what was hypothesized or to not be relevant.

Contrary to what was expected, older individuals relocated faster than younger individuals. For each additional year a person is older when taking a new job, tenure at their older home decreased by 1.98%. Individuals that would relocate to a rental unit spend 27% less time at their residence than people who purchase their next location, and those that were renting their residence at the time of finding work relocate 36% sooner than homeowners. Owners are more committed to their residences, and the costs of relocation are much higher to them than to renters. Those who plan to own also take longer to relocate because the home search takes planning and time. Since home ownership involves risks that renters do not endure, getting into the “right” home

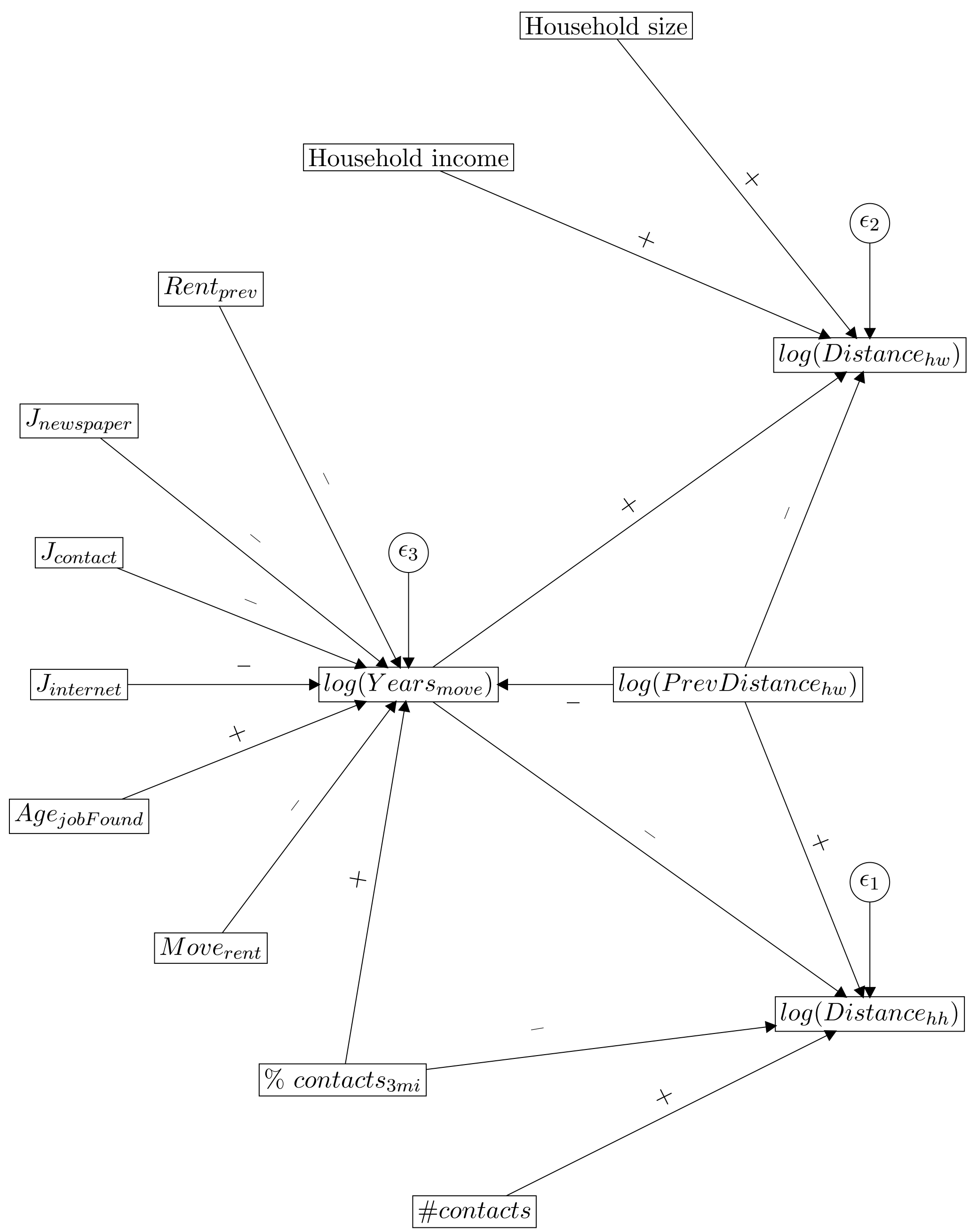


Figure 5.2: Proposed path model of tenure, commute, and moving distance after finding employment (correlations between exogenous variables not shown.)

can be a more deliberate process.

Table 5.4: Goodness of Fit of Measures

	Chi-squared	df	p	NFI	NNFI
Null Model	333.16	78	0.000	-	-
Estimated Model	15.10	19	0.716	0.955	1.063

Those who found their job through the internet stayed the least amount of time at their residence when finding a new job. Since the trend for internet users persists even after controlling for age and distance, there may be unseen variables among those that use the internet to find jobs that makes them footloose and less attached to their residential location. Those who used contacts have the anticipated direction, but the magnitude is less than that for internet users, and statistically it is not significant. The estimate for newspaper users is as anticipated, but it too is not statistically significant.

These observed variables have direct and indirect impacts on the home-to-work distance after relocation (D) and how far away from their current home individuals relocate (D_{hh}). The home-to-work distance after relocation depends weakly on how soon the relocation occurred, but is strongly related to what the commute distance before relocation was, and with household income. Each percentage increase in 'previous home-to-work distance' is positively related to the new home-work-distance. It suggests that those who had tolerated longer commutes before, will tolerate them still after a move.

Though not statistically significant, the model also suggests that those who experienced the previous home-to-work distance for a longer period of time after finding their work also had longer commutes. This is consistent with the idea that those who do not relocate quickly relocate for reasons other than commute. A household's income also plays a role in the home-to-work relocation after a move. With each $1,000 increase in household income, the new home-to-work distance increases by 2.7%. This is consistent with our hypothesis that wealthier households might be concerned about other aspects

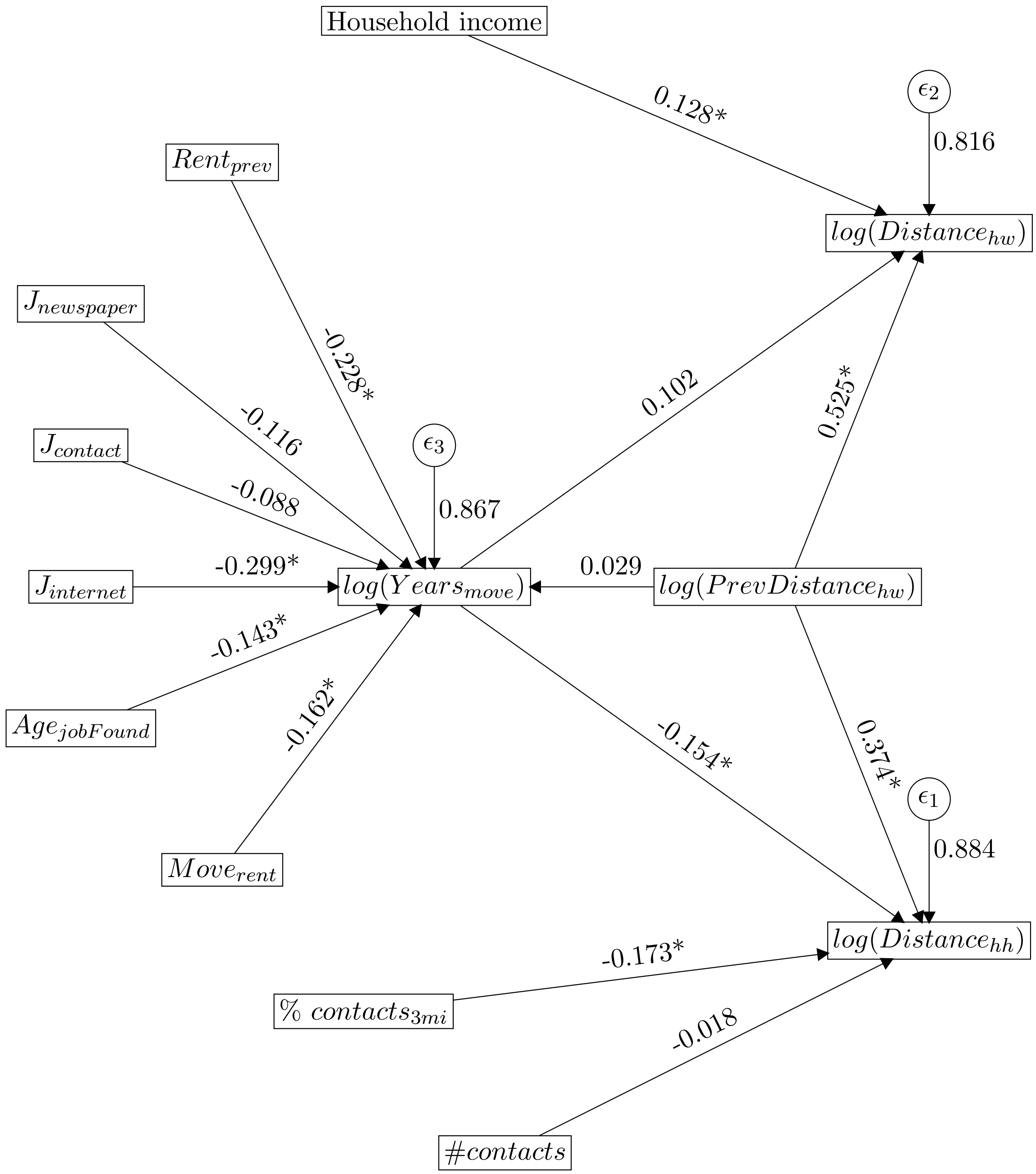


Figure 5.3: Estimated path model of tenure, commute, and moving distance after finding employment (correlations between dependent variables not shown. See Table 5.6). Estimates that are significant at the .05 level are marked with a *.

that are not commute related. No direct relationship was found between household size and home-to-work distance.

In choosing the new neighborhood, another factor that is considered is how far away the person moves from their previous neighborhood. The D_{hh} variable measures this distance. As hypothesized earlier, an important consideration for how far people moved from their previous location is assumed to be neighborhood quality as well as the contacts that they would leave behind. The model shows that those that didn't relocate as quickly did not relocate farther. For each additional year stayed at the home before relocation, the previous home to new home distance reduces by 1.6%.

Another important variable that indicates how far a person moves is the percentage of contacts that live around them. Here the role of contacts is clear. The model suggests that for each percentage gain in the proportion of close contacts in a 3 mile radius, the relocation distance from their previous home is reduced by 0.9%. The significance of the relationship supports the hypothesis that the people who have a larger proportion of their contacts close by try to stay close to those contacts when moving.

5.5 Summary

This chapter looked at commuting outcomes of job finding, and the commuting outcomes of relocations. One of the hypothesis that was tested is that job search methods can impact the commute distance because of the ways in which information is gathered. Specifically it was hypothesized that jobs found through internet searches would be on average farther out than traditional methods. The findings from the first part of this chapter support this hypothesis. In addition it was also found that commute distances from newspaper found jobs were also longer than jobs found through formal means or contacts.

The relationship between job search, tenure, relocation, and social networks was also studied using path analysis. The findings suggest that relocation costs (renting before, and moving to a rental) were instrumental in how quickly individuals relocated after finding their work. Job searchers who used the internet to find their current employment also relocated faster reinforcing the hypothesis from the first section of the analysis.

Contact found jobs did not show particular patterns in regards to residential tenure. Other social network variables were found important in the relocation choice. For example, the percentage of contacts that are within a 3 mile radius of a person (self-reported) has a negative relationship with how far away one relocates. This suggests that social networks have an influence over residential location decisions. This role, though essential from the decision makers perspective, may limit the reductions in commute that may be achieved through relocation.

Table 5.5: Estimated path model for relocation after finding work

		Variable	Estimate	Std. Error	t-stat
Time between finding work and relocation ($log(Y_{mv})$)	Distance before move	$log(D_p)$	0.030	0.070	0.43
	Job through contact	J_c	-0.155	0.135	-1.14
	Job through internet	J_i	-0.875	0.198	-4.41*
	Job through newspaper	J_n	0.278	0.180	1.55
	Age job taken	A_j	-0.020	0.010	-2.06*
	Moving to rental?	R_c	-0.317	0.149	-2.13*
	Rented before move?	R_p	-0.444	0.142	-3.12*
	Error variance		0.555		
	Total variance		0.740		
	R^2		0.249		
Commute distance after move ($log(D)$)	Years to move	$log(Y_{mv})$	0.103	0.064	1.59
	Distance before move	$log(D_p)$	0.541	0.066	8.17*
	Household income (1000)	I_h	0.027	0.014	1.97*
	Error variance		0.499		
	Total variance		0.750		
	R^2		0.335		
Previous to new home distance ($log(D_{hh})$)	Years to move	$log(Y_{mv})$	-0.164	0.073	-2.24*
	Distance before move	$log(D_p)$	0.406	0.076	5.32*
	Num. of contacts (/10)	C	-0.009	0.036	-0.26
	% of contacts in 3mi	C_{p3}	-0.009	0.004	-2.46*
	Error variance		0.655		
	Total variance		0.837		
	R^2		0.218		

Significance: * p-value ≤ 0.05

Table 5.6: Correlations among exogenous variables for relocation after finding work (only those above 0.1 reported)

Variable 1	Variable 2	Correlation
A_j	C	0.159
A_j	C_{p3}	0.126
A_j	R_p	-0.215
R_c	R_p	0.258
I	R_c	-0.285
I	R_p	-0.253
J_c	I	0.107
J_c	C_{p3}	0.138
J_c	R_p	-0.122
J_i	A_j	-0.178
J_i	R_c	0.277
J_i	I	-0.141
J_i	R_p	0.173
$log(D_p)$	I	0.184
$log(D_p)$	J_i	0.109
$log(D_p)$	C	-0.112
$log(D_p)$	C_{p3}	-0.192
C	R_c	-0.169
C	R_p	-0.131
C_{p3}	R_c	-0.141
C_{p3}	R_p	-0.169

Table 5.7: Overall and indirect effects of exogenous variables on relocation, commute and tenure

	Overall effect			Indirect effect	
	$log(D)$	$log(D_{hh})$	$log(Y_{mv})$	$log(D)$	$log(D_{hh})$
$log(D_p)$	0.544	0.401	0.030	0.003	-0.005
J_c	-0.016	0.025	-0.155	-0.016	0.025
J_i	-0.081	0.13	-0.792	-0.081	0.130
J_n	0.029	-0.046	0.278	0.029	-0.046
A_j	-0.002	0.003	-0.020	-0.002	0.003
I	0.027	0	0	0	0
C	0	-0.009	0	0	0
C_{p3}	0	-0.009	0	0	0
R_c	-0.034	0.054	-0.329	-0.034	0.054
R_p	-0.046	0.073	-0.448	-0.046	0.073
$log(Y_{mv})$	0.102	-0.164	0	0	0

Chapter 6

An agent-based Model of Worker and Job Matching

6.1 Introduction

In chapter 1, it was argued that the job search process, including job advertising, searching through different media, employee screening, as well as offers and offer-acceptance decisions, affect the observed job-worker match. Chapter 4 illustrated that different socio demographic characteristics are related with the successful search path a worker uses. In chapter 5 it was shown that different search paths can influence the final commute outcome, with home to work distances for those that used the internet and newspapers shown to be longer than those who used other methods. This chapter proposes and tests an agent-based model of worker and job matching. The model takes residential locations of workers and the locations of employers as exogenous and deals specifically with the interactions between firms and workers in creating a job-worker match and the commute outcomes. It is meant to illustrate that by explicitly modeling the search process and the interactions between firms and individuals, origins and destinations (ODs) can be linked at a disaggregate level that is reasonably true to the actual process.

Labor economist have used search theory (20, 21) to explain the behavior of searchers in the labor market. The approach conceives of searchers that are faced with randomly arriving offers, which they can choose to accept or reject. Optimal stopping and searching decisions are often investigated and depend on what the searcher knows about wage distributions, offer arrival rates, and the marginal costs and expected gains of waiting for the next offer. Works by Rouendal (33, 32), van Ommeren et al. (31, 34, 35, 36) have used a search based approach to study the relationship between jobs, residence and commute where individuals maximize lifetime utility based on wages, place utility and commuting costs.

Urban economists on the other hand have proposed models that take work place locations as exogenous, and theorized about the choice of residential locations. Models of this type include those of Alonso (28), Muth (94) and Mills(95). In the mono-centric city model, residential locations are assumed to be selected such that higher travel costs are compensated by cheaper land prices. Later works, for example by Hamilton (48), White (96), have shown actual commutes to be higher than predicted by these models, though to different degrees. Van Ommeren et al. (34) also show that models that assume transportation costs are fully compensated for by wages overestimate the wages required to compensate workers with longer commutes because they ignore residential relocation decisions. Similarly, they show that residential (place) utility need not fully compensate workers commute costs because of the possibility of future job changes. While the possibility of future moves can account for some of the observed longer commutes, other possible reasons are also cited in the literature including within household effects of multi-worker households, increasing importance of non-work trips and other housing and neighborhood attributes (50). In addition, information imperfection in the job and residential search process, costs of relocation as well as the very low rate at which employment offers reach job searchers have also been cited as possible explanations (36).

Earlier in chapter 5, data collected for this study showed that the commute often did not play a primary role for people who relocated their residence while at their job. In many cases people seem to maintain their commute rather than achieve a significant reduction (see figure 5.1), and only 17% reported their primary reason for moving as commute related. National figures from the Census Bureau for 2004 (79) also showed only 16% of movers citing work related reasons as their primary reason for relocating. Levinson (51), using metropolitan Washington data, also shows that those who change residences, on average, maintain their commute durations. Wachs et al. (80), looking at employees of a particular firm over a period of six years, find that those that have relocated during this period have tended to have longer commutes. These findings suggest that residential moves are dominated by other considerations than the reduction of commute time. However, people's reluctance to increase their commute substantially still highlights its importance in the decision framework.

Most search models reasonably assume searchers do not have complete information about all available jobs. While cost, as well as human capacity are part of the reasons for these, in some cases information barriers can be erected due to strategies adopted by firms. When considering commute outcomes, it becomes important to know of these systematic reasons especially when geographic targeting for example alters the possible application and offer rates that residents in some areas receive. Neckerman and Kirschenman (2) for example find that employment of inner city Blacks is hampered by recruitment practices which, when targeting neighborhoods, avoided inner-cities. The economic benefits of hiring through referrals for firms is illustrated by Fernandez et al. (97). Such a strategy for example would significantly lower the chances of individuals not-connected to current employees to know of open opportunities.

Further, applicant screening criteria adopted by employers can also influence the outcomes for certain classes of people. While reasonably objective criteria such as education and experience (1), or objectively negative indicators such as job hopping and lateness (98), are employed in screening applicants, the wide availability of research on discriminatory practices also highlights how employer policies can affect the job-worker match, and therefore the commute.

Given that both employer policies on advertising, screening, hiring, as well as worker strategies in searching are instrumental in forming the job-worker match, the proposed model looks at both sides using an agent-based framework. The structure that is created by the interaction of searchers and firms suggests that even if minimizing commute time were a goal for searchers, it would have to be done within the context of what opportunities are known by the searcher. In brief, the model operates by having employers solicit applications to fill their open positions and unemployed workers searching and competing for employment. Having received interested applicants, firms undertake a screening step to filter out those that do not meet their hiring criteria, and select the best matching candidate from the remaining applicants. Workers, both employed and unemployed, search for opportunities, submit applications to those that they consider worth pursuing, and accept or reject offers based on what alternatives they have and their current state. Both workers and jobs are assumed to have skills and skill requirements respectively that are important in matching one another. Other social factors, such as the presence of contacts for example, are also assumed to have a role in promoting certain job-worker matches to occur.

As chapters 4 and 5 have illustrated there are some patterns that may be found by looking at demographic variables but the process is clearly much more complicated than what can be captured by demographics. By adopting an agent-based modeling approach, the labor market and the experiences of workers including what information they have can be explicitly modeled. The next section discusses the agents involved in the model and what kind of actions they can take, that is followed by the rules by which agents interact with one another and make decisions. Finally the model is applied to a subset of individual and job data extracted from the 2000 Travel Behavior Inventory (TBI) data for the Twin Cities area and the results are discussed.

6.2 The Model

The model proposed here matches origins and destinations using employment search methods at the individual level. The outcomes depend on travel preferences of the searcher, skills, pay, the locations of employment opportunities, and the willingness of firms to employ the searcher. The geographic plain on which the modeling is undertaken contains both employment locations which may be flexibly arranged into one or multiple employment zones or be randomly distributed as well as residential locations. Firm and housing locations are assumed to be exogenous. Workers will search for employment from fixed home locations.

The model contains both active agents which interact with one another through out the simulation and inactive agents which are mainly used to mark location and to house employment opportunities.The inactive agents in this model are job centers, where firms are located, and the firms where employment positions are housed. Job centers and firms are present to give structure to the location of employment opportunities. Job centers (which may be one or many) house firms, and firms house employment opportunities. The presence of job centers is optional. When job centers are not present firms can be distributed through out the modeled area randomly. All employment opportunities are housed within a firm to which they are randomly assigned. The active agents in this model are the workers and employment positions which interact with one another in determining job opportunities and pay scales, and negotiate agreeable arrangements for employment. Each of these agents are discussed below.

6.2.1 Job Centers

The purpose of job centers is to house firms. These are established as optional fields where a mono-centric, poly-centric, or a city with distributed employment can be modeled in the the home-job matching process. The location of the job centers can be at any location on the plain that is being modeled, though when mono-centric models are considered the location has been fixed at the center of the geographic area.

6.2.2 Firms

Firms house employment locations. When job centers are present, firms can only locate in only one of the job centers. Assignment of firms to job centers is done randomly at the start of the simulation. In the current model, once a firm chooses a location, it does not relocate. Employment locations are also assigned to the firm randomly. Once employment positions are assigned to them, firms know how big they are what types of positions they have. Though the number of employees at a particular firm may change, the number of positions that are available at each of the firms does not change throughout the simulation.

6.2.3 Employment Positions and Workers

Employment positions are housed in Firms. Each employment position has characteristics that it requires fulfilled by potential employees (or a minimum skill set that is needed to be fulfilled). The skill set required by any position (J_q) is assigned as a randomly generated integer ranging from one to five. Each of these is assumed to be increasing in specialization and commands an average pay that is higher than the preceding level. Each position is assumed to have an amount that it is willing to pay an employee. At the start of the simulation, the pay that positions are willing to offer is assigned to the jobs by pulling from a uniform distribution whose mean is a function of the position's skill level as shown in equation 6.1 and whose range is \$10,000. Alternatively, wage dispersion can be set to 0, leaving the wage to be only a function of the desired skill.

$$W_o = J_q * 10000 + W_{disp} * Q_p \qquad \begin{cases} Q_p \sim Unif(0, 10000) \end{cases} \tag{6.1}$$

where

J_q: the job-class for the position.

W_o: is the amount that the position offers to pay prospective employees.

Q_p: is a random draw from a uniform distribution with a range of $10,000.

W_{disp}: indicates whether there is wage dispersion at a given skill level

At any given time, a positions can be open or taken (closed). When open, job seekers may find and apply to occupy positions. When not open, a position is not searchable and does not take any applications. Employment positions know how well applicants as well as the person occupying them matches the requirements of the job. Each employment position acts as would a human resources department in real life, by accepting and screening applications as well as making offers and negotiating a salary with qualified applicants. When they have difficulty attracting talent, positions increase their offer pay at each iteration.

Workers start out randomly assigned to residential locations from which they search for jobs. Workers residences are assumed to be stationary. Each worker is randomly assigned a skill class (S_c) that corresponds to the job-classes (J_q) for the employment positions. At the start of the simulation all workers are seeking employment. They search for open positions that fit their skills and put in applications reporting their qualifications. Each worker is also assumed to have a minimum wage (W_m) that they would want to accept any job offer. This is set at $W_m = S_c * 5000 + W_{disp} * Q_a$, where $Q_a \sim Unif(0, 5000)$. At the beginning of the simulation, each worker also has an expected wage (W_e^u) which is set 10% higher than W_m. Once the searcher is employed, their expected wage (W_e^e) will be set greater then or equal to their earnings at the time of search.

Workers are assumed to have limited information on available positions that match their skills. To find information, workers have to start searching for opportunities with some intensity I. Different workers can have different search intensities that describes how many applications they put in at any given time slice. A worker only receives offers from those positions to which it has applied.

Though skill matching is an important part of the model, workers are allowed to apply to positions for which they are slightly under or over qualified. They however are assumed to avoid applying to untenable positions by comparing their skill class (S_c) with the job class (J_q) of the employment position. Some portion of the searchers can use a contact to gain access to employment. A proportion of these contacts are assumed to be influential and can leverage their position to increase the match between the applicant and the open position even though the match of skills to criteria may not be perfect (or perhaps better matches may be available).

The model allows for individuals to receive any number of offers at a given time given they have applied to the position, and they are selected as the best applicant for that position. When several job offers are made to the respondent within a given iteration, the model assumes they arrive such that they can be compared against one another simultaneously. Once an offer is made to a worker, searchers choose which offer is the best and decide to accept or reject the offer by comparing its offer wage and transportation costs to their current situation. The selection process may be specified so that a deterministic decision framework is adopted where the highest offer is chosen, or a probabilistic decision is made based on travel time and salary considerations within the expected utility framework. Decisions are also assumed to be made only on the basis of offers and current wages or reservation wages. Workers do not know what the likelihood of offers in the next time slice will be. Offers that improve the net present value of their net income (wages minus commuting costs discounted over expected tenure) are always accepted. Further all workers' residential locations are assumed to be fixed.

When searching, those that are already employed adjust their asking pay so that it is higher than their current salary. Those that are unemployed will lower their asking wage until it reaches their reservation wage for each iteration that they remain unemployed. To stay competitive employment positions also offer annual increases for their employees. In part these raises ensure long term employment is realized. The raise amount is randomly generated from a uniform distribution and implies a variability in the wages offered for similar positions. Researchers have empirically shown that similar workers receive markedly different wages for similar types of jobs (99, 100) whose existence has been theorized to arise from different reasons including employer wage policies, as well as unmeasured worker abilities (101).

6.2.4 Job Search and Matching

At the start of the simulation all workers do not have jobs and all positions are open. Workers start out deciding with what intensity I they will search for a job. The search intensity determines the number of applications a worker submits at a given iteration of the simulation. A global variable sets the minimum and maximum search efforts for the agents. Workers apply to positions that are they deem are reasonable fits for their skills. After picking the intensity with which to search, workers sample I positions that satisfy equation 6.2 and submit applications. In cases where I exceeds the number of positions available that meet the application criteria, the worker applies to all available qualifying positions.

$$|J_q - S_c| \leq tol \tag{6.2}$$

where:

J_q: Job class for a position being considered

S_c: Skill class for the searching individual

tol: A global tolerance level among searchers for under or over-qualification

When the tolerance level is set to 0, workers only apply to jobs that are a perfect match to their skills. Greater numbers imply over or under-qualified applicants can also apply and compete for a position. There are at least two factors that can make slightly under-qualified applicants appealing to the employer. First is that their asking salary may be lower as compared to more qualified searchers. Second, job searchers may use contacts to find employment, a proportion of whom may be able to influence the outcome of the hiring process. Two global variables in the model P_c and P_{cl} control the proportion of people who find jobs through contacts and the proportion of those whose contacts can leverage their relationship with the employer to assist in better matching respectively. Currently whether a contact is used and whether the contact is influential is set randomly according to probabilities equal to P_c and P_{cl} at each iteration, and no information as to the identity of the contact is generated.

6.2.5 Evaluating Applicants and Making Offers

Open positions which have received applications evaluate each applicant using two steps. In the first step employers remove unqualified applicants from the pool and retain only those applicants that satisfy equation 6.3. Positions then randomly sample one of the qualified applicants and extend an offer.

$$S_c + C_l \geq J_q \tag{6.3}$$

where

J_q: Job class for the position being considered

S_c: Skill class for the applicant j

C_l: Whether applicant j used an influential contact

6.2.6 Weighing Offers and Searcher Decisions

Workers that the employer selects as best meeting their criteria receive offers of employment. A searcher may receive more than one offer depending on where they applied and whom they competed against. The decision on the part of the searcher to accept any given offer proceeds in two steps. First, the applicant selects which offer they regard as the best among the competing offers. Second this best offer is weighed against the current state that the searcher is in. A decision is made whether to accept the offer or remain in the current position by comparing the net present value of their income stream less transportation costs over their expected tenure. The selection of the best offer among competing offers is done by weighing the travel distance and the offer wage in an expected utility framework. The Probability that a person considers offer k the best among the competing offers made to them is calculated according to equation 6.4.

$$p_{ij}^{b} = \frac{e^{\beta_{1i}*T_{dj}+\beta_2*W_{oj}}}{\sum_{k=1}^{n_{offers}} e^{\beta_{1i}*T_{dk}+\beta_2*W_{ok}}} \tag{6.4}$$

where

p_{ij}^{b}: The probability that worker i selects offer j as the best among competing offers

T_{dj}: The daily travel cost (round trip travel time to the offered job) of offer j (in hours)

W_{oj}: The offer pay that position j is willing to pay (\$/day)

β_{1i}: The coefficient for travel cost for person i.

β_2: The coefficient for wages (set at 1).

The parameters for the utility function are selected so that individual level differences are allowed in the travel cost variable. The marginal rate of substitution between travel cost and wages is selected so that it represents the agent's expected wage when searching. With β_2 fixed at 1 for all individuals, this would mean that -β_{1i} = W_{ei} for person i. The selection of β_2 to be equal to 1 is arbitrary. Any other selection would not alter the order of preferences for any given set of alternatives though the probabilities may change.

Once a searcher determines the best offer, this offer is then compared to their current position using the net present value of staying where the agent is currently and the new offer over the expected tenure of the new position. The net present value calculation takes into consideration income and transportation costs only, and at a yearly discount rate γ, it is calculated as shown in equation 6.5.

$$NPV_{t_e} = \sum_{t=0}^{t_e} \frac{W_k - VOT * T_{dk} * N_w}{(1+\gamma)^t} \tag{6.5}$$

where

NPV_{kt_e}: the net present value as a result of being at job k for an expected tenure of t_e

W_k: annual wage at job k

VOT_k: value of commute time for person j at job k (assumed W_k)

T_{dk}: The daily travel cost (round trip travel time to the offered job) of offer j (in hours)

N_w: Number of working days in a year

γ: the annual discount rate

t_e: the expected tenure at the new position

This value is calculated both for the current job that the individual holds and the new best offer that the individual receives. If the NPV of the best offer is higher than that for the current job, then and worker chooses to accept the new position; otherwise, they will stay and continue searching. Searching and job relocation costs are assumed negligible in the NPV calculation. Workers will accept the offered job as is if it is above their expected pay. When the offered salary is less than what is expected by the searcher, a negotiated salary is assumed that is randomly determined to be between the offered salary and the expected salary. This new salary serves as the basis of future search when the worker decides to search again.

6.2.7 Changing Employment

Each year after a worker has found employment, they re-evaluate whether or not they should search for an alternative position. While several reasons may motivate searching for another position while already employed (on-the-job search), here we assume the probability to search for another job is a function of tenure. Farber (102) makes two observations that are important here about the U.S. labor market. First is that long term employment relationships are common, and that beyond a certain point, workers will choose to stay with their current employer; and second, that most new jobs end early. The overall effect is that with increasing tenure, the probability of job change declines (102). Here, the probability for on-the-job searching is modeled so that it is decreasing with tenure. Each year the probability that a person would want to change employment is given by equation 6.9. If a search at any given time was not successful, the workers will have to decide whether or not to search in the next cycle.

$$p_{rel} = 1 - \frac{e^{(t_r - \bar{t_r})}}{1 + e^{(t_r - \bar{t_r})}} \tag{6.6}$$

where

p_{rel}: is the probability of wanting to change jobs

t_r: tenure at current employment

$\bar{t_r}$: the tenure for the population beyond which the probability to start searching for another job declines below 0.5 (a global variable in the model).

6.2.8 Competition

In trying to match one another, both employers and workers can make themselves attractive to each another. Each year that a position remains open, it can increase its offer price to attract applicants. Similarly workers that are unemployed can make themselves attractive by reducing their asking price each iteration they remain unemployed until they reach their minimum pay. Those that are currently employed and searching can increase their expected wage by adding a few percentages to their existing salary. Similarly employers can also increase the wages paid to their current employees each year to counteract any incentives that rising offers at open positions may have. These adjustments are assumed to be random draws from a distribution whose maximum is specified at each run. The increases in offer price and wages as well as the decline in asking price are assumed to decrease in percentage terms as the length of search or tenure increases. In reality, employed individuals retire and budgets exist for how much a firm is willing to pay for a particular position. By implementing these caps, a position at any given skill level increases the wage offered only to a point when it remains unfilled. Expected wages also decline to a minimum beyond which the person is unwilling to work. Alternatively, by setting these percentages at zero, one can assume that salary offers are exogenous to the search process and the search can be conditioned on these fixed salaries. These cases are compared in the following section using a simplified urban landscape.

$$W_{o,t} = W_{o,t-1} * (1 + \gamma_o^{f(u_o)}) \tag{6.7}$$

$$W_{e,t}^u = max(W_{a,t-1}^u * (1 - \gamma_c^{f(u_s)}), W_{min}) \tag{6.8}$$

$$W_{e,t}^e = W_{t-1} * (1 + \gamma_r^{f(t_r)}) \tag{6.9}$$

where:

$W_{o,t}$: Wage offer at time t

$W_{e,t}^u$: The expected wage at time t, when the person is unemployed

$W_{e,t}^e$: The expected wage at time t, when the person is employed

W_t: The wage received at time t by the searcher

γ_o: The rise in offer wages by employers, $\gamma_o \sim U(0, \gamma_{o,max})$

γ_c:The decline in expected wages when unemployed, $\gamma_c \sim U(0, \gamma_{c,max})$

γ_r: The rise in wages each year a person remains employed, $\gamma_r \sim U(0, \gamma_{r,max})$

u_o: the number of iterations the offering positions has stayed open

u_s: the number of iterations the unemployed worker has been searching

t_r: tenure at the current position

$f(.)$: function, here equal to $f(x) = \frac{x}{10}$.

6.3 Testing with simplified models

The model as described was implemented using NetLogo (103). A screen shot is given in figure 6.5. To see if the model gives reasonable outcomes, tests are performed using simple urban structures where workers are randomly generated and employment is concentrated at a finite set of locations. The simplest scenario is the mono-centric urban model where all employment is at one location. However, since neither workers' residences or workplaces are allowed to change, this model would have everyone working at the core and travel times would be determined by where housing is located relative to the center. Hence we start with a slightly more complicated landscape where there are four employment zones, each located at the center of a quadrant that divides the modeled area into four zones.

To simplify the model, the total number of employment opportunities available at each employment zone are made equal. A total of 520 workers are also randomly generated and distributed through out the plane, but with each quadrant having equal number of residents (see figure 6.1). Several versions of this layout are tested while changing different variables in the model but without altering the landscape (the location of employment and workers' residences). In the simplest cases tested, it is also assumed that there is no skill differentiation, and no wage dispersion at the given skill level. Each of these are relaxed and the commute outcomes of the model are compared. In addition, different combinations of minimum and maximum search effort, and the possibility of contacts enabling matching are also modeled.

Four test cases that illustrate how the model matches workers and jobs are discussed next. Under each of these cases one or two variables are change to illustrate how the OD matching is affected. In case 1, all jobs and workers have no skill differentiation and all wages are the same. In case 2, wages are assumed to have a uniform distribution but no skill differentiation exists. In case 3, skill differentiation exists, wages are also an increasing function of skills, however there is no wage dispersion at any skill level. In case 4, skill differentiation exists and for 25% of workers searching for work, contacts can improve their chances of hire if they are under-qualified for a position. Three skill levels are assumed but there is no wage dispersion at at any skill level. In each of these cases the search intensity for each agent when searching is a random draw from a uniform distribution ranging from 0 to 5. Each model is run until no employment changes occur for any agent for 50 consecutive iterations. Table 6.1 summarizes the main attributes of these cases.

Figures 6.1 to 6.4 show the matched home and work outcomes from one typical run under the described case. For clarity only the home-work connections for the jobs located in one quadrant are shown. The large black dots are the employment centers, and the small red dots are the workers (located at their residences).

The first case, as expected, leads to the shortest home to work distances. Most of the workers in the quadrant also live in the same quadrant. The outcome is similar in each of the other quadrants. The average home to work distance in this case is 16.3 units. In case 2, all attributes of the model 1 are kept the same, with only wage differentiation allowed. In this case the wage offered by any one position is a random draw from a uniform distribution between $10K-$20K. In this case the average distance travelled rises significantly to 23.3 units. In case 3, each of the jobs as well as workers is randomly assigned one of three job classes. Here again, matching the differentiated skills leads to higher home to work distances. Case 4, also leads to higher distances as positions relax their requirements and allow under-skilled but socially connected individuals, but much of the rise is accounted for by skill differentiation. Indeed there is no a-priori reason for jobs found through contacts to lead to shorter commutes unless the process occurs through neighbors who themselves have short commutes.

In moving from the simplest model (case 1) to a model with wage dispersion (case 2), the sum of commute distances rises by about 40%. The model with skill differentiation (case 3), leads to a rise of about 7.5%.

Table 6.1: Model parameters for illustrative cases

case	tol	I_{min}	I_{max}	Job classes	$P_c * P_{cl}$	W_{disp}
1	0	0	5	1	0	0
2	0	0	5	1	0	1
3	0	0	5	3	0	0
4	1	0	5	3	0.25	0

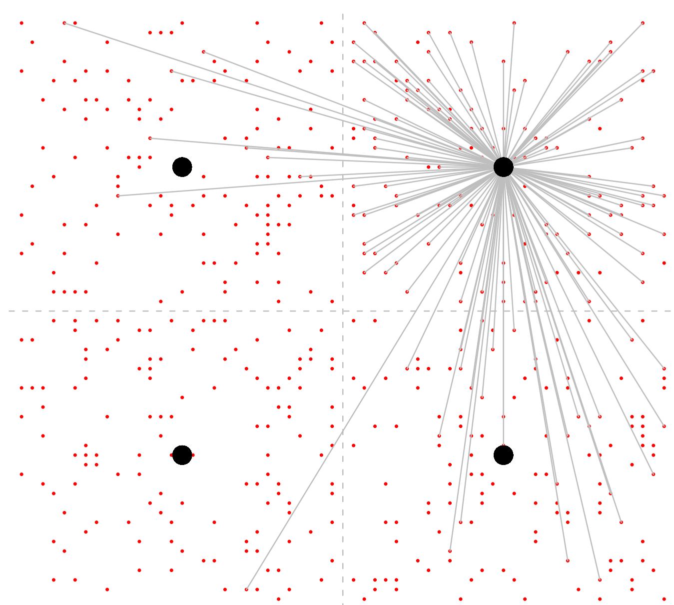


Figure 6.1: Case 1: Simplest model, no skill or wage differentiation

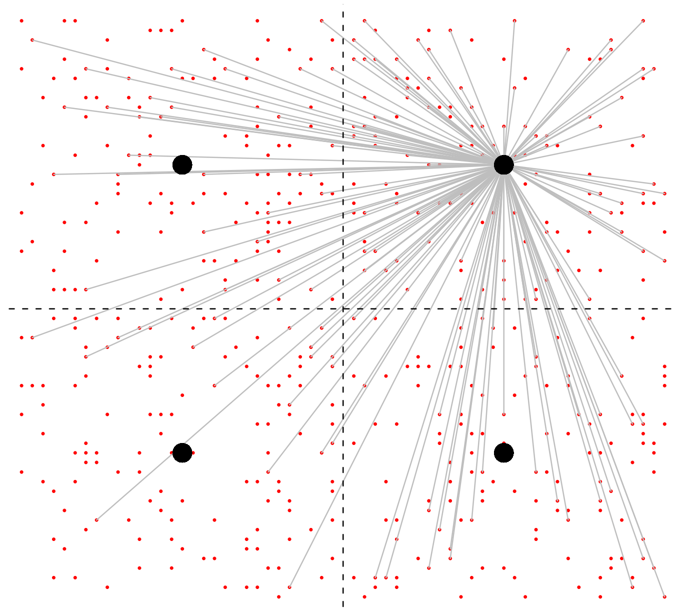


Figure 6.2: Case 2: Wage differentiation, no skill differntiation

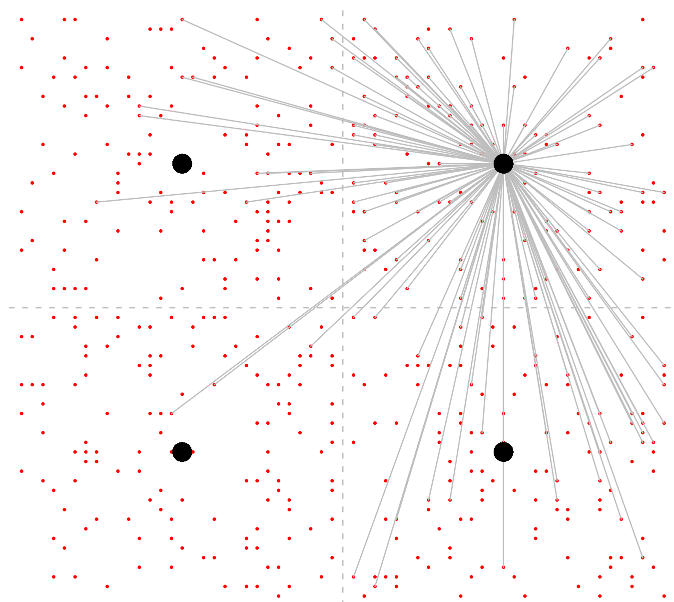


Figure 6.3: Case 3: Skill differentiation, no wage differentiation at a given skill level

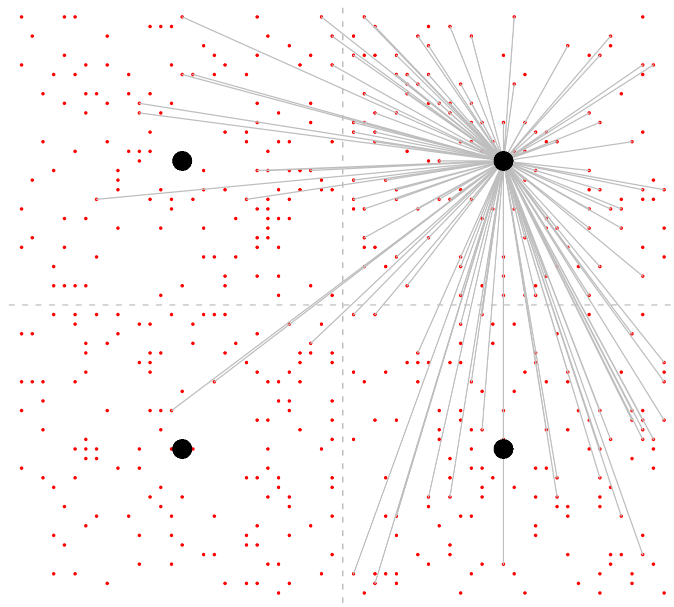


Figure 6.4: Case 4: Contact influence and skill differentiation

6.4 Model Stability

To test the model's sensitivity, the commute outcomes to different combinations of the input variables is tested. Two general cases are studied. In case 1, wages are taken as exogenous to the search process and adjustments do not occur as described in section 6.2.8. In this case γ_o, γ_c, and γ_r are all set to 0, which means only the expected wage when employed rises to the wage currently being paid. In the second case, each of the rise proportions (γ_o,γ_c,γ_r) are assumed to be random draws from a uniform distribution between 0 and 0.05. The input variables in each case are the existence of wage dispersion, skill differentiation, the use of influential contacts, and the skill mismatch tolerance in considering applicants. In each of these tests the minimum and maximum search intensities are set to be random draws from a uniform distribution between 0 and 5. Each of these factor combinations are set to two levels for a 2^5 factorial design. The 32 different combinations are run 25 times each, for a total of 800 simulations over which the commute outcome was evaluated. In each of these runs, the employment locations are fixed, while residential locations are freely chosen within each quadrant.

The results from these tests illustrate the model is stable within replications, and responds in a consistent manner to adjustments of the variables in the model. Table 6.2 presents an analysis of variance on the mean home to work distance under the tested combinations. Changes in the variables of the model account for the majority of the behavior that is observed in successive runs of the model. About 80.4% of the variance in the average commute outcome is accounted for by the levels of the factors. Wage dispersion accounts for a significant amount of the variance. In transitioning from the simplest model (Case 1) to one where there is wage dispersion, the average home to work distance rises by 5.5 units as searchers compete for the best fitting job available.

Table 6.2: Analysis of variance for test model

	Df	Sum Sq	Mean Sq	F value	Pr(>F)
Wage rise	1	1228.92	1228.92	675.94	0.000
Wage rise:Match tolerance	2	391.12	195.56	107.56	0.000
Wage rise:Skill differentiation	2	39.55	19.78	10.88	0.000
Wage rise:Contact use	2	57.20	28.60	15.73	0.000
Wage rise:Wage dispersion	2	4181.93	2090.97	1150.09	0.000
Residuals	790	1436.29	1.82		

6.5 Testing the Model with Minnesota Data

The model was applied to a subset of the 2000 TBI (Travel Behavior Inventory) data for the Twin Cities region. This data set was chosen because it includes disaggregated individual data for workers and the location of their of employment. Consideration was also given to using the LEHD data set which was earlier used in chapter 3; however, while the LEHD includes blockgroup level data for both income and sector of employment, there is no link between these two variables at both the residential and workplace ends. Hence it is not possible to know which sectors are paying what amount to workers in a blockgroup. The downside to using the TBI is that the data does not contain employment sector information or more details that could be used on the workplace. Nonetheless, the disaggregate detail allows the individual level identification of each worker, and the identification of the skill required and salary for the jobs reported by the respondents by using the respondents' education level and income reported.

On the worker side, because income is reported at the household level, for this test application, only single worker households that reported one job and lived and worked in the metropolitan area are used. While it is still possible that the reported income by respondents includes non-wage income, additional assumptions about how income should be subdivided among workers in multi-worker households as well as between jobs from second employment would not have to be made. A total of 805 individuals were extracted from the data who, in addition to the above criteria, had also reported their education level. The education level was used to classify the skill level of the respondent as well as the job-class of the respondent's place of employment into one of five categories. On the job side as well the education level of the person who reported the job is used as the job-class. Once these data are extracted, the link between home and work are severed, and the challenge is to re-establish the link using the agent based model.

Before running the simulation, certain modifications had to be made to the model to make it work with the TBI data. First the definition of job classes as well as skill classes had to be adjusted. Since the data includes the education data of respondents and where they work, each job is marked as requiring the skill class of the person who currently occupies it into five categories. Searchers skill class was also marked by their education level. The five categories used for skill classification correspond to "11th grade or less", "High school graduate", "2 years of college/Associate's Degree", "4 years of college/Bachelor's Degree" and "Post-graduate". The minimum pay as well as the initial expected pay of each worker is set to be 75% of their final reported income. On the other hand the offer pay at the start of the simulation for the positions is set

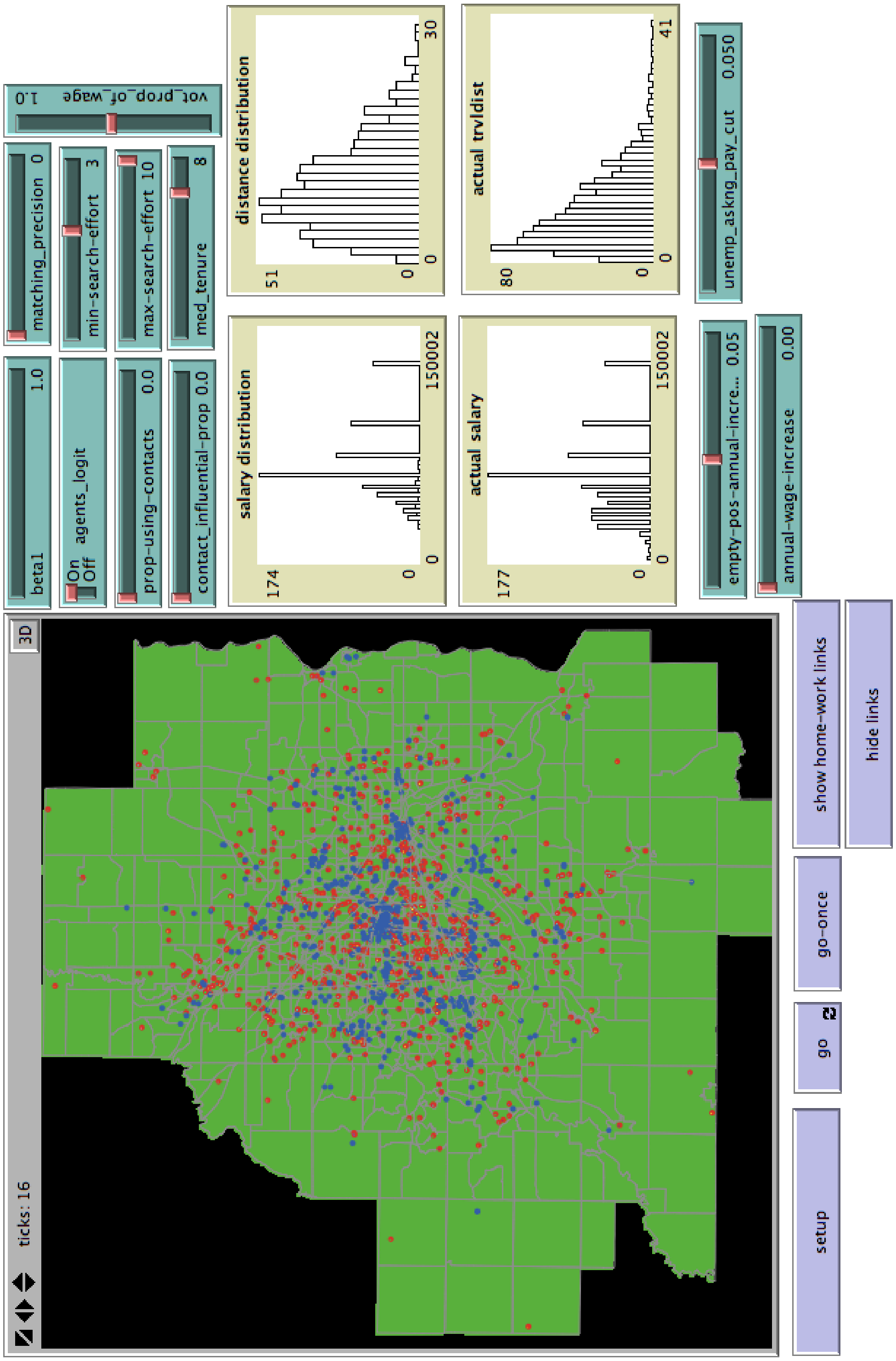


Figure 6.5: Netlogo model of job-worker matching screen shot

at the income per worker-in-household that the respondent reported. This was done because the data showed a very weak connection between the reported education level and reported income.

In addition to these modifications, parameters of the simulation were set to reflect the limitations imposed by the data. The matching tolerance (tol, equation 6.2) was set to 0 and the proportion of contacts that were influential (P_{cl}) was also set to zero in this model. Other aspects of the model remained the same. Different combinations of I_{min}, I_{max}, γ_o, γ_c, and γ_r were used to run the simulation to replicate the distribution of distances as observed in the TBI data. Since the actual salaries are used as the offer wage for each position, wage dispersion is present in the model relative to the educational requirements of the position. The tested combinations of the model parameters and the values that replicated the commute distribution for the workers adequately are shown in table 6.3. Comparisons between actual commute distances and the simulated distances was done using a t-test. The best-fit parameters in table 6.3 below consistently reported no difference in the overall distribution of home-to-work distance with p-values greater than 0.25. Figures 6.6 and 6.7 show the counts of individuals in different commute and wage categories from 200 simulations using this model.

Table 6.3: Model parameters

Variable	Values	Best fit
I_{min}	0, 3, 5	3
I_{max}	5, 10, 15	10
γ_c, γ_r	0, 0.5	0
γ_o	0, 0.05	0.05
P_{cl}*P_c	0	0
tol	0	0

Figure 6.6 suggests that actual job finding within a 2.5 mile radius of the respondents' home occurs at a greater rate than the model could predict. It suggests that job searching in the vicinity of the home is perhaps more intensive within this radius than

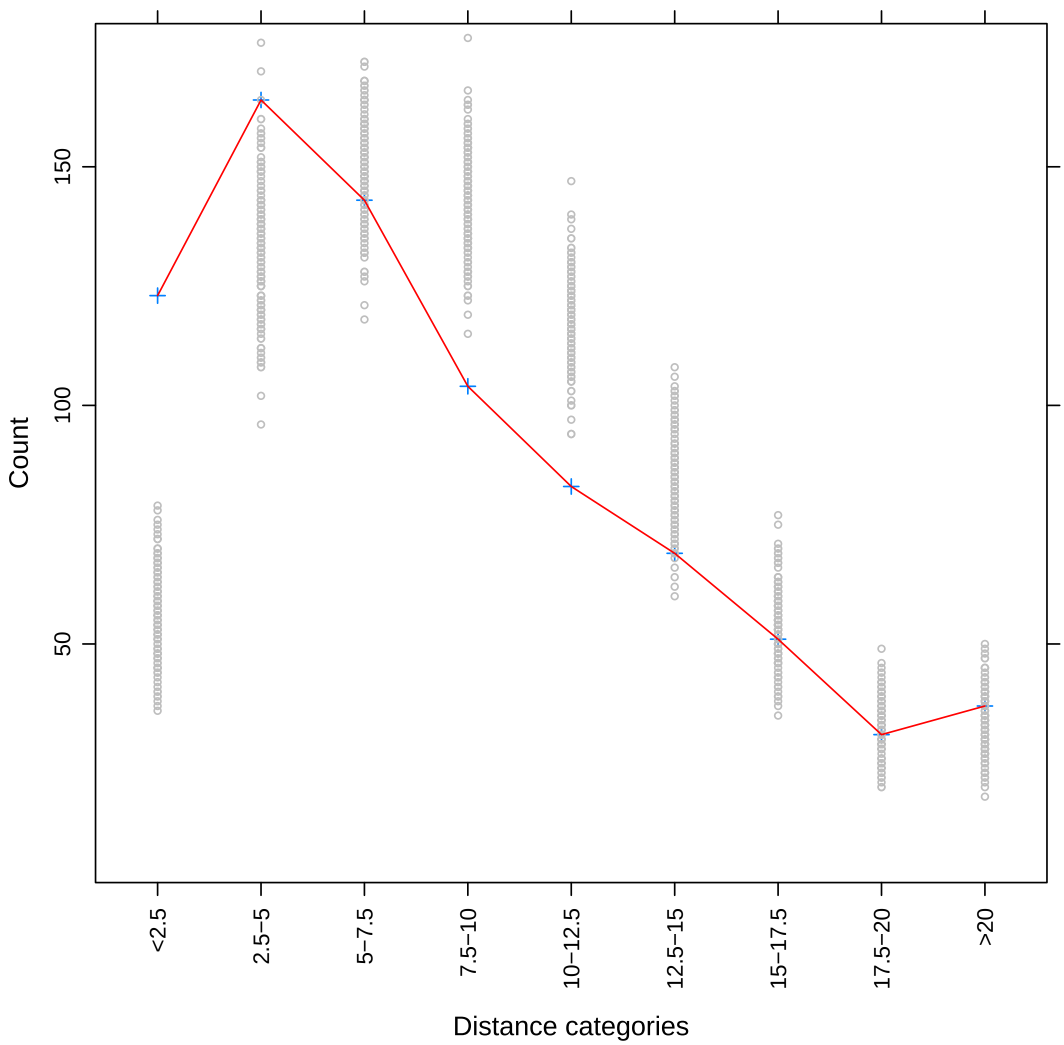


Figure 6.6: Comparison of actual count of individuals in trip length categories against the job-worker matching model output

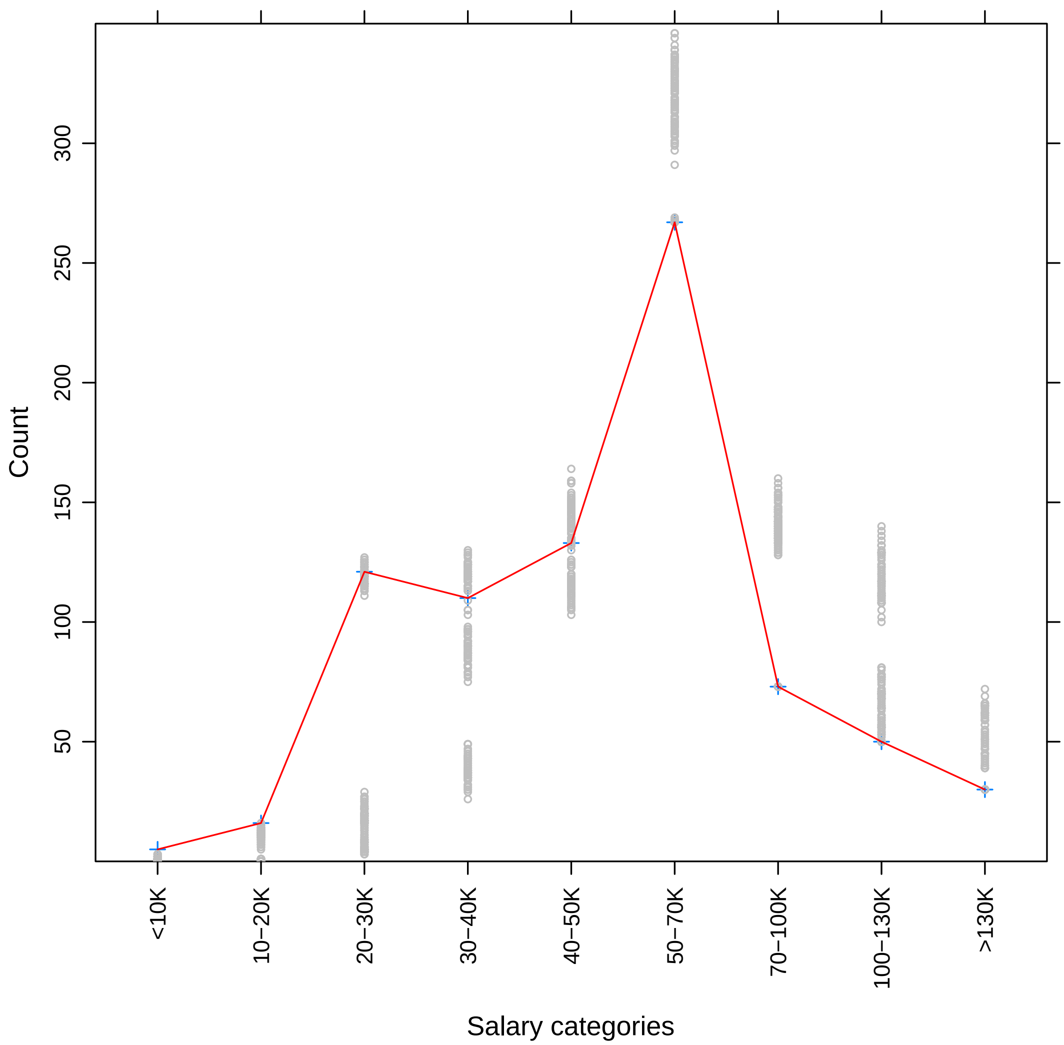


Figure 6.7: Comparison of actual count of individuals in income categories against the count from the job-worker matching model

it is outside. Alternatively, this may also be the result of relocation decisions after job finding or a combination of both. The proportion of jobs predicted at each of the other categories seem to be reasonably predicted by the model.

While on aggregate the model replicates both the salary and distance distributions well, individual level fitting does not perform as well. In part this is because the data on jobs and workers only uses their education as a basis of skill and job class to perform the matching. As a result employment opportunities that are not exchangeable in reality are assumed to be exchangeable in the model. In reality information on sector, job type, experience, in addition to education can be used to segment the population of workers and jobs to improve the matching given data can be gathered on these variables. Figures 6.8 and 6.9 show a plot of actual salaries and incomes at the individual level as compared to the simulated results one run of the model. While the increasing trend appears correct, there is considerable variance within each income and commute category. This variance can potentially be reduced by the use of more refining methods that narrow search categories for a given worker. Future extensions should look at both the data needs, and ways to integrate existing data into the search framework.

6.6 Summary

This section illustrated that an agent-based job matching model that explicitly considers the matching process can be used to simulate the home-work match between workers and jobs. The test urban area illustrated that the model leads to reasonable outcomes, with agents selecting the closest work place when wage and skill differentiation is absent. Relaxing these assumptions increases the observed commute. Especially the introduction of wage dispersion in the model increases the the average home to work distance significantly. Using Minnesota data, the results on aggregate have been shown to capture the trends in the observed data, and illustrate that the behavior rules as implemented lead to reasonable patterns. But weaknesses were present when individual

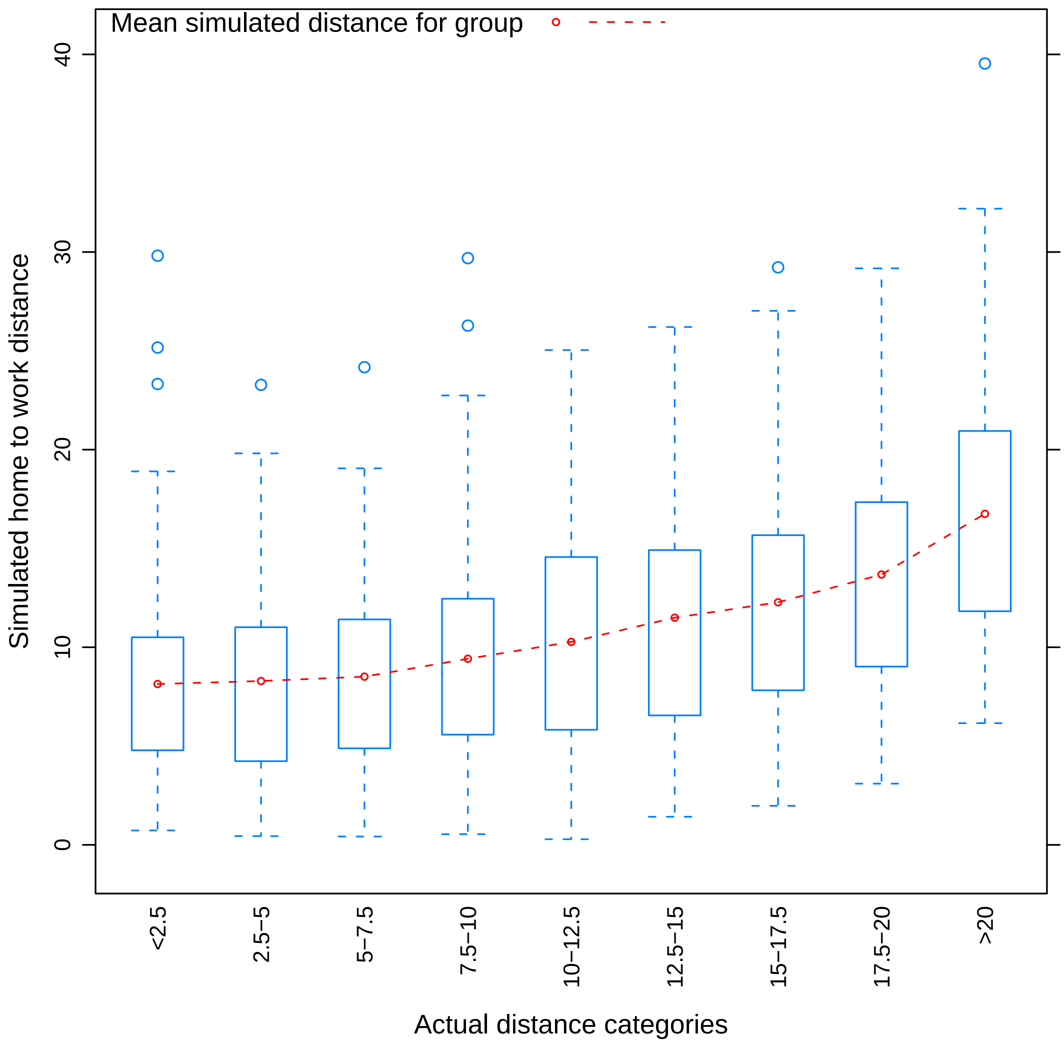


Figure 6.8: Simulate distance and actual distance (correlation $(r) = 0.36$)

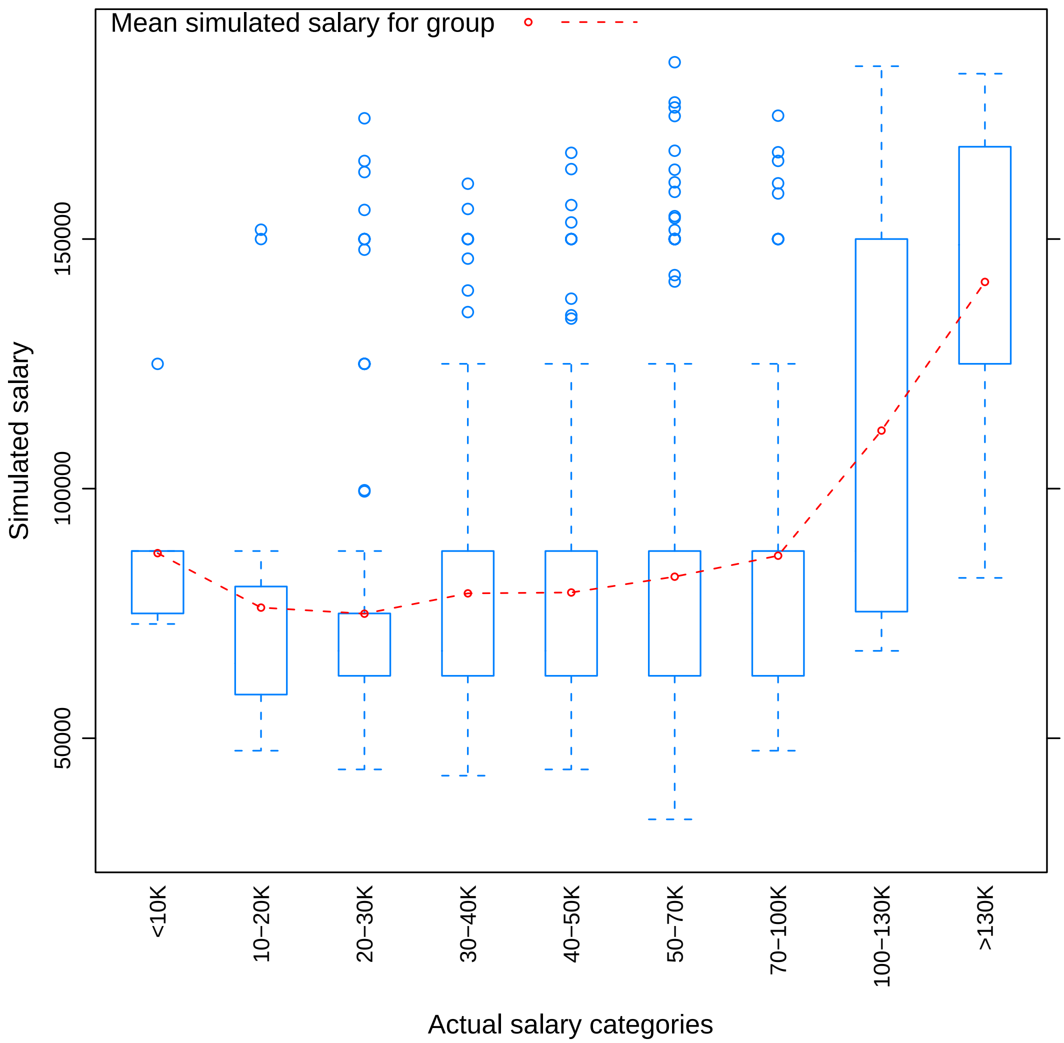


Figure 6.9: Simulated wages and actual wages (correlation $(r) = 0.37$)

level data were compared. In part these weaknesses are the result of insufficient details on the job seekers and employment opportunities. This is because the data used was geared towards the development of more aggregate models.

At least two lines of further work are essential. The first, and most important, is to improve the matching by incorporating better detailed information on both searchers and jobs so that matching can further be refined. In the current data for example, the connection between reported education levels and wages tended be weak. Therefore, better ways of gauging the skill needs of employment positions and wages offered are needed. The data needed to more fully test the proposed model would need to include at a minimum the following details. On the searcher side, data on skills and experience which go beyond education levels and ask specific streams of study as well as areas of expertise are needed. In addition, wage data on the current employment and location are required. These information should be collected for each worker in a household. On the employment side, details on jobs would need to be more specific than the education level. The type of job, the industrial class of the firm, the experience of who is holding it, as well as the wages that are paid are also essential. In addition, to better develop the decision mechanisms, information from searchers on alternatives considered and how they knew of them, as well as data on firm strategies on advertising their openings can allow better targeting of the information within the agent-based model.

A second line is to incorporate the effect of residential location (and relocation) in affecting the home-work match and commute. The current model for example assumes that individuals do not relocate. However some of the home-work commute observed may have resulted due to relocation. These extensions can strengthen the model and make it useful not only for OD matching, but also for testing different policy prescriptions that may impact both job search and commute outcomes. By adopting such a model, the sensitivity of agents to a wide variety of variables can me modeled while accounting for differences in their tastes.

Chapter 7

Social Meeting Location Decisions

7.1 Introduction

Thus far we have looked at how the search process, including the use of contacts influences the home-work match. Another dimension that we will investigate in this chapter is the role played by social networks in travel for social activity engagement. Social activity travel is an important part of a household's total travel. According to the 2001 National Household Travel Survey, on average social and recreational travel accounts for 24.5% of a household's annual distance travelled (104). Continuing on the theme of social networks from the preceding chapters, this chapter explores the more direct travel related role that social contacts play in the selection of meeting locations.

The need for social interactions, both in personal and professional settings, is at the center of many of our mobility needs. Many of our activities involve other people, some of whom are close to us on a personal level, and others who we are acquainted with at a distance and many more whose presence is necessary to the activities we engage in without knowing them personally. The social dimension of travel is often implicit in statements such as "travel is derived from the demand for activities" [which often involves others]. Social contacts affect our decisions where and when we engage in particular activities. Our choices of destinations for meeting friends depend as much on whom we are meeting and their preference as our own. It is plausible then that explicit consideration of who is involved in the activity may shed more light on the choice of destinations and the allocation of time.

The need for co-presence with other people is obvious in many of the activities we undertake. With the expansion of communication technologies, possibilities of reduction of face to face meetings were expected. Dijst (105) proposes that the spread of these technologies would encourage decoupling of activities and places, continuously reconfiguring where physical and electronic communications occur but would not lead to the irrelevance of distance. Urry (106) points out that even in today's highly networked environment, co-present conversations are an essential part of social and economic life. He points out that such meetings enable the establishment of long term relations that require trust.

Investigating the role of social networks in social-activity travel, Carrasco et al. (66) find that there are systematic effects related to actors and their networks that affect the spatial distribution of social interaction. Proposals for incorporating the social network paradigm into activity-travel behavior have been made by Arentze and Timmermans (67). Hackney and Axhausen (65) propose an agent model of the interdependence of social networks and travel.

Advances in communication technologies add an interesting dimension to this complexity. Due to the instant access one has to an increasing number of contacts at all times of the day through mobile phones and other technologies, meetings can now be scheduled and rescheduled on short notice. Lower technological costs also mean more frequent interaction through these other means and that may lower the need for face-to-face meetings. Expanding communication possibilities also exist with higher bandwidth and the expanded use of video communications via computers. Urry (106) also points out that technology based meetings are good for task oriented relationships. This may also mean the availability of more time to interact with those close contacts of value to the individual.

While these technologies may alter how, when and with what frequency we interact, we are not yet at a point where face-to-face engagement is about to become a thing of the past. Spending "face time" with someone implies sharing the totality of the environment at that moment. Such interaction often takes longer, and is relaxed in the sense that there isn't a need for constant back and forth over the course of the meeting. Widely available technologies do not afford such an experience; first, because the parties are in two different environments, and second, because they require either constant engagement over the duration of the communication (as in a phone conversation) or are asynchronous (as in email). In both cases, albeit to varying degrees, there is little chance of a shared experience in the moment that leads to new and sustained conversation as would happen in face-to-face meetings.

Social meeting travel has much less structure than travel to work. Its frequency can vary significantly from person to person or even for the same person from week to week. It is dictated not only by the schedule of the traveller of interest but also by who else is involved in the meeting. Meeting location can vary from day to day, as can the time at which the meeting takes place. In fact, any structure that exists in social activity travel may come from the fixedness of working hours, employment locations, household constraints of the meeting parties and the operating hours of the meeting locations (when meetings occur outside the home) and the physical limitations that Hagerstrand (12) discusses.

7.2 What Gives Social Meetings Structure?

For workers, one can posit that a significant amount of structure to the times, duration and location of meeting is imposed by the locations of home and work, and the time constraints placed by employment and household responsibilities. Countering these effects is the role played by technological advances from faster transportation modes to communication technologies that enable scheduling of meetings as time slots open, as well as transportation cost reductions and car ownership that enable traversing of long distances in short amounts of time.

The availability of a wide range of communication technologies has possibly cut down on meetings that otherwise would have required face-to-face interactions, or removed the temporal constraints that phone conversations place on the parties involved. Access to the internet and email enable conversations to occur without constraining the parties involved to participate in the back and forth in real time. On the other hand, with expanded use of mobile phones and the "instant" access it affords to contacts, scheduling/rescheduling is made much easier. One can easily call on a friend when in their neighborhood today than it was perhaps possible two decades ago because more people can be readily reached. In the past contacts would have to be sought at their home or work place in advance where they had land lines to be reached.

One can think of positive and negative constraints on face-to-face social interactions. Work schedules, family responsibilities, sleep and rest requirements tell us when these meetings are unlikely to occur. On the other hand, these constraints are weakened by the ability to free up time by using passive technologies to interact with many others, and by the additional ability to organize meetings on very short notice. The ability to telecommute and having a flexible work schedule also loosen these constraints.

The availability of multiple modes of communication at different costs allows users to pick and choose how they meet with different contacts. Here the type of relationship that one has with the contact influences meeting decisions such as where one meets (at home/out-of-home) and creates tradeoffs on how far one is willing to travel for a face-to-face meeting.

In the following sections data collected to study the interdependence of personal characteristics, type of relationship, meeting purpose and meeting location is described.

That will be followed by an analysis of meeting locations in-home or out-of-home. Finally out-of-home meetings are studied by considering the dependence between relationship type, meeting duration, and home to meeting distance along with other demographic variables.

7.3 Data Summary

The data for this portion of the study comes from the survey described in chapter 4. This section summarizes the data on meeting location, duration, purpose, relationship of the person that meetings took place with, and so on. In addition it examines how respondents use different communication media to maintain their relationships as well as schedule their meetings. The next section investigates the interrelationships among these variables and personal characteristics.

The analysis is limited to meetings that are local (happened within the metropolitan area). A one week meeting diary based on recall was collected from the participants of phase 2. Respondents were asked to "list all scheduled meetings you had in the last 7 days outside of your work location" and to include "all meetings with family, friends, get togethers, parties, civic engagements, meetings for personal/home related tasks, first time meetings, etc." There were 744 meetings from 222 respondents that took place within the metropolitan area.

Just over a third of these meetings (33.9%) occurred in-home, either at the respondent's residence or their contact's residence. The proportion of meetings that occur inside a home on weekdays is smaller than on weekends. Of 737 meetings for which location and date is known, in-home meetings make up 26.3% of weekday meetings, and 44.1% of weekend meetings. Weekday meetings are significantly more likely to be out-of-home than weekend meetings. During the weekend, 65% of meetings reported by single females were out-of-home, while 50% of meetings reported by single men were out-of-home. For multi-person households the figures are 45.9% for men and 46.9% for women. For weekday meetings on the other hand, 83.3% of meetings for single men occur out-of-home, 79.1% for single women, and 70.5% and 72.5% for men and women of multi-person households respectively.

Table 7.1 shows the average and median home to meeting distances on weekends and weekdays respectively. The first two columns and the last column only look at out-of-home meetings only. In general meetings tended to be closer to home than to work. When meetings take place at family/friends' homes on weekends, both the average and median distances were longer than the other categories. Meeting locations with family and friends, when they occur out-of-home, are similar to the overall weekday and weekend averages.

Table 7.1: Distances for out-of-home meetings (mile)

Distance: (mean/median)	home to meeting	work to meeting	home to friend's or family home	home to meeting (family/friend only)
Weekday	7.26/6.13	9.5/7.93	8.68/7.32	7.20/5.89
N	349	334	161	44
Weekend	7.59/6.34	9.98/9.26	13.25/12.03	8.52/7.0
N	144	138	78	46

Meeting locations including the in-home meetings from the one week diary are shown in 7.1. Over the period of seven consecutive days, many people had more than one meeting. The distribution of number of meetings per person is given in figure 7.2. The sudden drop from the number of people that had six meetings to those that had seven meetings might in part have been affected by the survey layout. Because responses for the seventh entry and on were on a second page, some of the respondents may have found it too demanding to fill out. This may mean that the analysis here underestimates the number of meetings that people make and that it may not capture the full geographic scale of the meeting locations. Despite this problem, we still have a large amount of information to analyze the location of meetings relative to the respondent's home and

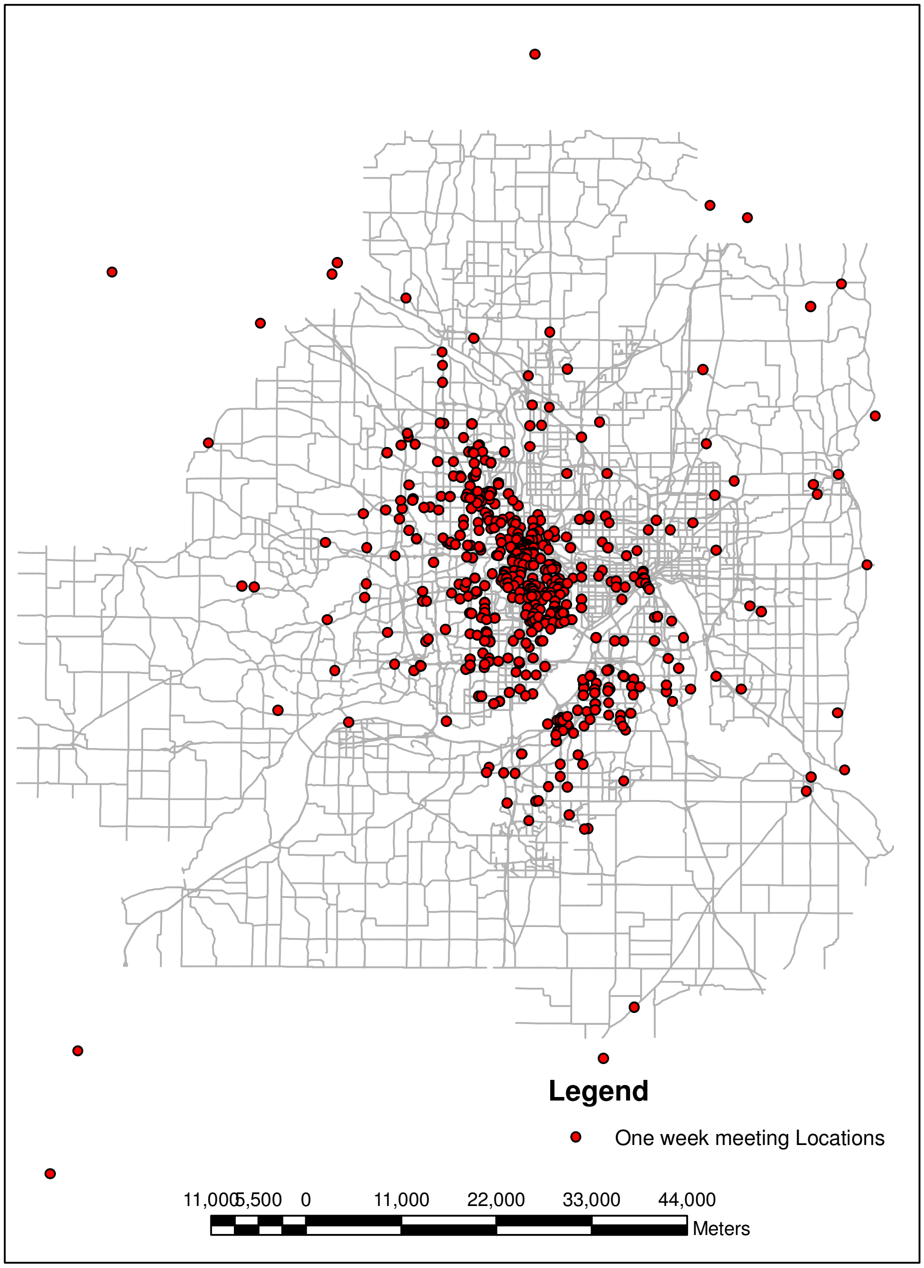


Figure 7.1: Respondents meeting locations

work.

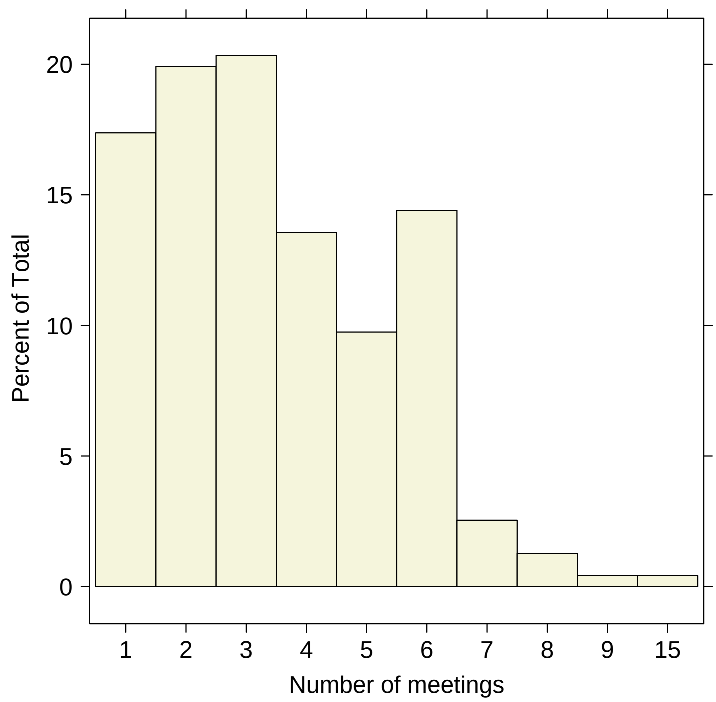


Figure 7.2: Number of meetings for respondents on the week prior to taking the survey

About half of the out-of-home meetings reported in the one week period are with close friends (30.3%) and family (18.1%). These two groups also constitute 58.3% of all meetings (including in-home meetings). The rest are divided between business coworkers and other contacts as shown in table 7.2. Meetings that involve more than one person constituted 6.2% of all out-of-home meetings.

7.4 In-home and Out-of-home Meetings

Decisions on where to have a meeting depend on a variety of factors that have to do with the person's characteristics, circumstances of the meeting and the location of opportunities around them. In this section we will first investigate what motivates the

Table 7.2: Proportion of meetings by contact relationship

Contact type	Percentage of all meetings	Percentage of out-of-home meetings
Close friend	33.21	30.32
Family	25.12	18.07
Coworker	7.48	10.04
Business contact	6.25	8.63
Church Contact	6.00	8.23
Social club contact (book clubs etc.)	4.90	5.22
Distant Friend	3.06	3.61
Neighbor	3.19	1.81
More than one person	4.90	6.22
Other	5.39	7.43
Unreported	0.49	0.40
	100%	100%

in-home/out-of home decision for a meeting. It is assumed that in-home meetings are fundamentally different from even those meetings occurring very close to home. In-home meetings are generally with people one feels a stronger affinity to. A person may be comfortable inviting a contact to a neighborhood coffee shop but not necessarily into their homes.

In addition to the nature of the relationship between the meeting parties, whether a meeting occurs at home may be motivated by the purpose and anticipated duration of the meeting. It is expected that meetings at home would have longer durations. In addition, it is also expected that at leisure meetings are more likely to occur at home than other types of meetings.

Individuals that have more of their contacts close to their home are expected to have in home meetings more often than individuals with fewer friends close by. Household characteristics are also expected to be important. Larger households are expected to have more meetings at home than smaller ones.

A binomial logit model that predicts out-of-home meetings as a function of the personal characteristics and the meeting variables is specified as follows:

$$log(\frac{\pi_l}{1-\pi_l}) = \beta_0+\beta_1 C_r+\beta_2 M+\beta_3 T_{mt}+\beta_4 F+\beta_5 Y_h+\beta_6 W_{end}+\beta_7 C_{p3}+\beta_8 G+\beta_9 E+\beta_{10} H$$

where

π_l: The probability that a meeting occurs out-of-home

C_r: Close contact (identified as family or close friend)

M: Meeting purpose (1=leisure, 0=otherwise)

T_{mt}: Meeting duration (in 10 minute increments)

F: Does the person telecommute? (1=yes)

Y_h: Tenure at home (years)

W_{end}: Weekend (yes=1)

C_{p3}: Proportion of contacts in 3 miles of respondent's home

G: Gender (male=1)

E: Education (0=high school graduates, 1=above High school)

H: Household size (1=single, 0=otherwise)

The estimated model is given in table 7.3. The model captures the overall tendency to have meetings out of home rather than in-home in the intercept term. The nature of the relationship with whom the respondent is meeting has a significant influence on the location of the meeting. Meetings with close contacts were less likely to occur out of home as compared to meetings with less closer contacts. In the data about 58% of meetings were with close contacts - close friends, and family. Overwhelmingly close contacts tend to be met at home (or at their home). Seventy five percent of in-home meetings were with family or close friends. out-of-home meetings on the other hand are divided 48% to 53% as being with close and distant contacts respectively.

Table 7.3: Binomial logit model of in-home/out-of-home meeting choice (1=out-of-home, 0=in-home)

		Estimate	Std. Error	z value	Pr(>|z|)
(Intercept)		1.547	0.416	3.72	0.000***
Close relationship	C_r	-0.553	0.219	-2.53	0.011*
Meeting purpose	M	-0.785	0.246	-3.19	0.001**
Meeting duration	T_{mt}	-0.092	0.059	-1.56	0.118
Telecommute?	F	0.515	0.217	2.37	0.018*
Home tenure	Y_h	0.029	0.013	2.22	0.027*
Weekend	W_{end}	-0.673	0.191	-3.52	0.000***
% contacts in 3mi	C_{p3}	0.670	0.529	1.27	0.205
Gender	G	0.160	0.208	0.77	0.442
Education	E	0.688	0.255	2.70	0.007**
Household size	H	-0.196	0.070	-2.81	0.005**
	Null deviance	797.11	df=644		
	Residual deviance	697.15	df=634		
	Psuedo-R^2	0.125			
sig	$*** < 0.001$	$** < 0.01$	$* < 0.05$	$. < 0.1$	

Table 7.4: Predictive accuracy of in-home/out-of-home meeting model

		Predicted probabilities of meeting being out-of-home	
		$< .5$	$\geq .5$
Actual location	In-home	59	140
	Out-of-home	45	401

The meeting purpose is also closely associated with the meeting purpose. Compared to the base category of non-leisure meetings, leisure meetings were less likely to be outside of the home. Business or other purpose meeting tended to occur out side of the home.

It is assumed that people have a general idea of how long a meeting would take and would make location decisions accordingly. The findings weakly suggest that longer meetings take place at home (p-val=0.118). But as will be shown later, when considering out-of-home meetings separately, longer meeting durations are also associated with longer meeting distances. The tendency for longer duration of in-home meetings can also be due to the fact that many of these are leisure meetings with close contacts, and are therefore less formal and can flexibly be extended.

Approximately 31% of the respondents indicated they occasionally telecommute to work suggesting some level of flexibility on their work schedule. On average these individuals tend to have meetings outside of the home as compared to their counterparts that responded they don't telecommute. Tenure at home is also significantly associated with in-home meetings.

The model also illustrates that weekend meetings as well as meetings of people with larger households tend to happen in-home relative to weekday meetings and the meetings of single households respectively. Finally those with college level education tend to have more meetings out of home relative to those with high school level education.

The C_{p3} variable, which measures the proportion of contacts that live in 3 miles of the respondent's residence is not statistically significant in predicting meeting location (p-val=0.205). Gender is also found not to matter in deciding whether a meeting is in-home or out-of-home.

Overall the model categorizes 71.3% of the observations as more likely to happen where they actually took place(Table 7.4). However, it falsely predicts in-home meetings as likely out-of-home in many instances. The model also suffers because information on the parties being met, whom one can assume had as much contribution as the individuals being considered here, is absent.

7.5 Out-of-home Meetings

For this part of the study we shall focus on meetings that occur outside of the respondent's or their contact's residence. It is hypothesized that the choice of out-of-home locations depends on the individual and their household constraints, as well as on who they are meeting including the nature of the relationship. Expectations on the duration of the meeting, and the availability of possible meeting locations in the neighborhood in which the individual lives is also expected to influence the meeting location. The interdependence of many of these variables on each other (e.g. personal variables on duration and distance, distance on duration, etc.) call for an integrated model where the structure of the data and the interdependence can be studied.

Duration and distance decisions are likely to be interrelated. For scheduled meetings, it is hypothesized that individuals would be willing to travel longer distances for longer duration meetings. Since meetings would revolve around some purpose whose duration one is likely to anticipate before hand, the meeting location decision is likely to be affected by it. The decision would try to balance duration and distance, as well as balance duration with other household and individual constraints. Weekend meetings for example are likely to be longer, just because work constraints on time are not present. Larger household sizes are likely to lead to shorter durations because of other household responsibilities on the person's time allocation.

A path model is proposed where the effects of different variables and their covariance is modeled explicitly. The structure of the relationship is imposed a priori as shown in Figure 7.3. Meeting duration is proposed to depend on individual characteristics such as age, education, household size, income as well as the characteristics of the meeting. The type of relationship the meeting parties have as well as meeting purpose are expected to influence the duration of the meeting.

The home to meeting distance is proposed to depend on the relative quality of the respondent's home neighborhood in terms of available meeting destinations, the flexibility of their schedules as well as demographic characteristics of the respondent. In addition, the concentration of contacts around their home and their home-to-work distance are also expected to influence the distance travelled in opposite directions. A positive relationship is also expected between duration and distance travelled. This structure is imposed because of the belief that duration largely depends on meeting purpose, and location decisions occur later depending on the purpose, the time needs and the environment that the meet requires.

The relative availability of destinations is measured as the ratio of the proportion of entertainment, food, and retail businesses in the residential blockgroup of the respondent, to the aggregate proportion of such businesses businesses in the metropolitan area. This number is less than 1 if the blockgroup has a lower proportion of these businesses, which can serve as meeting locations, relative to the metropolitan area. This is similar to how location quotients are calculated in economic base modeling. Here the number of businesses in a particular sector are used to calculate the quotient. Values greater than one indicate that relative to the metropolitan area the residence blockgroup of the respondent has a higher share of businesses that are focused on retail, food and entertainment.

The variables included in the final path model are:

D_{mt}: The home to meeting location distance.

T_{mt}: Meeting duration (in 10 minute increments)

C_r: The nature of the relationship (close contact vs. distant contact). Close relationships are those identified as family and close friend. (distant=1)

F: Does the person telecommute? (1=yes)

W_{end}: Weekend (yes=1)

H: Household size (1=single, 0 otherwise)

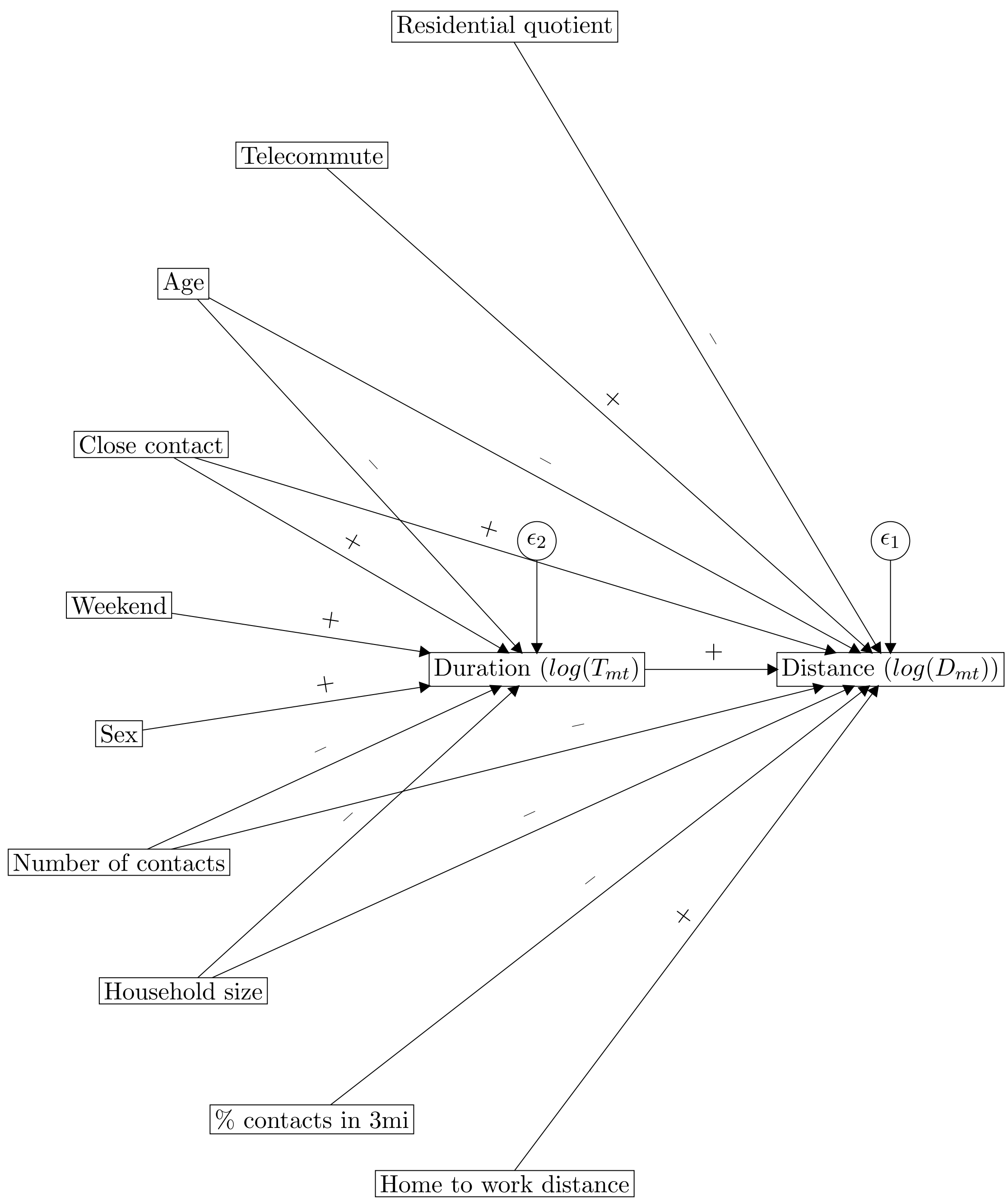


Figure 7.3: A path model of meeting distances and meeting duration for out-of-home meetings(correlations between trip variables are not shown)

A: Age of the respondent

Q: Neighborhood quotient, measuring if the respondent's block group has a higher proportion of food, entertainment, and retail businesses as compared to the metropolitan area as a whole.

Model fitting is done using the SAS/CALIS software (93). The goodness of fit measures for the model are given in table 7.5. The estimated path coefficients and correlations are summarized in tables 7.6 and 7.7. The chi-squared measure in table 7.5 compares the covariance matrix from the estimated model with the observed model. A large p-value is evidence that the estimated covariance closely resembles the observed relationships in the model (failure to find a statistical difference). None of the adjusted residuals exceeded a value of 1.2 in absolute value. Values of 0.9 and above in the NFI and NNFI indices indicate that the model provides an acceptable fit. Table 7.8 summarizes the overall and indirect effects of the exogenous variables in our model on meeting duration and home to meeting distance. Figure 7.4 shows the relationships between the variables using standardized path coefficients (i.e. these are similar to the coefficients that would be estimated if all variables in the model were standardized so that they have mean 0 and variance of 1).

Based on the analysis, the proposed model has been readjusted to reflect the best fit. For instance the link between age and meeting duration, number of contacts and distance as well as percentage of contacts in 3 miles and duration has been removed from the proposed model (figure 7.3). The R^2 values for the duration and meeting distance indicate the amount of variance in that is accounted for by the direct paths. The models suggest that even though the impact of the variables included suggests clear trends, there is still significant variance left in the model to address. But this is expected to some degree as meeting decisions are also affected by the meeting parties that are not included in this analysis, and can also easily be influenced by variables such as the "mood" of the person on that particular day etc. that are difficult to capture based on observed variables.

The path model suggests that age has a negative influence on distance. The older one is the less they travel to meet others. While not statistically significant, telecommuters tend to travel farther for meetings, and those that have a relatively higher concentration of retail and entertainment businesses with in their residential blockgroup tend to travel less for meetings. This is likely because of the ample number of destinations that can be used as out-of-home meeting locations. People who have a larger percentage of their close contacts within three miles of their home also have shorter home to meeting distances. Household size and home to work distance both impact meeting duration positively. A possible reason why individuals with larger household sizes have longer meeting distances is that they have meetings just after work, or as they run other errands outside of the home. On meeting duration, larger household sizes tend to shorten meeting durations as expected.

Home to meeting distances also increase with home to work distances positively. For each 10% increase in-home to meeting location, the home to meet distance increased by 1.3%. This suggests that the neighborhood around the work location is also an important meeting area. Coworkers make up 10% of out-of-home meetings and it is reasonable to expect at least many of the meetings with them and others are centered around the work location.

Table 7.5: Goodness of Fit of Measures

	Chi-squared	df	p	NFI	NNFI
Null Model	244.43	66	0.000	-	-
Estimated Model	6.34	10	0.786	0.974	1.135

Meeting duration on the other hand is significantly influenced by the type of relationship, the household size, gender, and meeting day. Meetings with close relationships are expected to take about 34% longer all other things the same. Weekend meetings are also 19% longer, and men tended to have longer meetings than women by 7.4%. Larger

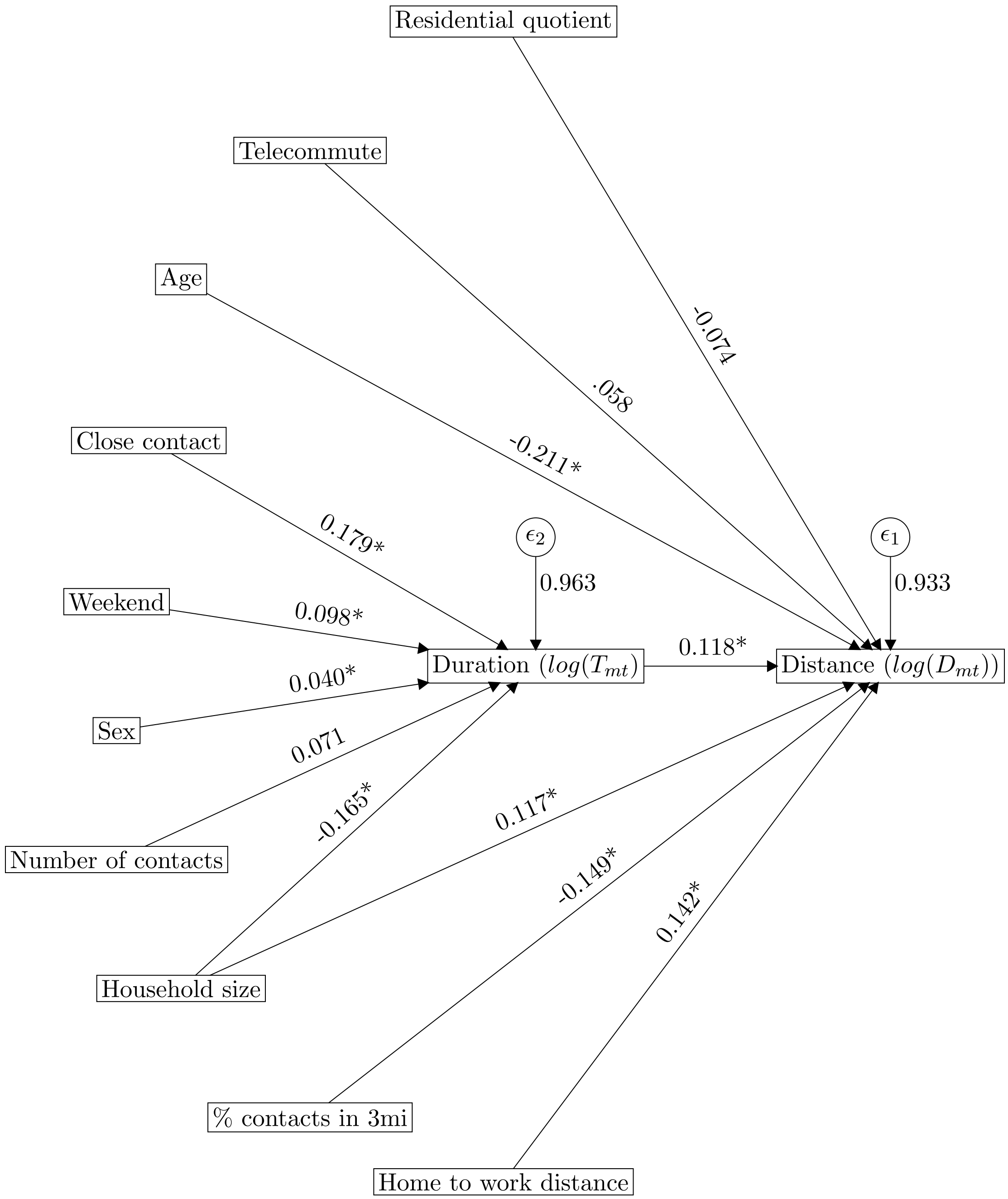


Figure 7.4: A path model of meeting distances and meeting duration for out-of-home meetings. Estimates are based on standardized data. See table 7.7 for correlation among independent variables.

Table 7.6: Estimated path model for meeting duration and home to meeting distance

		Variable	Estimate	Std. Error	t-stat
Home to meeting distance ($log(D_{mt})$)	Meeting duration	$log(T_{mt})$	0.114	0.049	2.341*
	Home to work distance	$log(D_{hw})$	0.134	0.048	2.797*
	Age	A	-0.014	0.003	-4.149*
	Household size	H	0.072	0.03	2.442*
	Telecomute (flexibility)	F	0.094	0.082	1.148
	Residence quotient	Q	-0.102	0.072	-1.407
	% of contacts in 3 mi	C_{p3}	-0.006	0.002	-2.795*
	Error variance		0.541		
	Total variance		0.622		
	R^2		0.13		
Meeting duration $log(T_{mt})$	Close relationship	C_r	0.291	0.084	3.481*
	Household size	H	-0.105	0.035	-3.036*
	Weekend	W_{end}	0.174	0.091	1.906*
	Number of contacts (/10)	C	0.037	0.028	1.311
	Gender (1=male)	G	0.072	0.03	2.442*
	Error variance		0.613		
	Total variance		0.661		
	R^2		0.073		

Significance: * p-value ≤ 0.05

household sizes have shorter meetings. The trend in the number of contacts suggests that larger social contact circle individuals tends to have longer meetings.

Longer durations are associated with higher distances travelled. A 10% increase in meeting duration, increases the distance one travels for the meeting by 1.1%.

The impact of duration on distances implies that the variables having a direct impact on duration have an indirect impact on distance. These effects are given in Table 7.8. The indirect impact of having close relationship with the contact, a weekend meeting and being male is positive. On the other hand household size has an indirect negative impact on distance through its impact on reducing meeting duration. Overall though its net effect of household size on distance is positive.

Table 7.7: Correlations among independent variables of the path model

Variable 1	Variable 2	Correlation
Q	C_{p3}	0.298
C_{p3}	G	-0.124
C_r	A	-0.153
$log(D_{hw})$	C_{p3}	-0.175
A	W_{end}	0.105
A	F	0.163
H	C	0.329
C_r	F	-0.103

7.6 Summary

The first six chapters in this dissertation have highlighted the role contacts play in home and work matching. This chapter looked at the role contacts play in both the location choice and the allocation of time to meetings. In general it is shown that the type of relationship, the meeting purpose and the individual's demographic background have a role to play in determining the location, the duration as well as the distance travelled for meetings. Mainly we have shown that in-home meetings tend to occur most often with close contacts and less often with distant contacts. The purpose, meeting day, and household size suggest that leisure, weekend and people with larger household sizes tend to have their meetings either at their home or at their contact's home. On the other hand less known contacts are met outside of the home. Meetings with closer contacts are associated with longer durations and indirectly with longer distances travelled. In addition, those with a larger proportion of contacts in a close proximity to them reported shorter distances.

Table 7.8: Total and indirect effects of model variables on meeting distance and duration

		Total Effects		Indirect Effects
		$log(D_{mt})$	$log(T_{mt})$	$log(D_{mt})$
$log(D_{hw})$	Home to work distance	0.134		
C_r	Close relationship	0.033	0.291	0.033
A	Age	-0.014		
H	Household size	0.060	-0.105	-0.012
W_{end}	Weekend	0.020	0.174	0.02
F	Telecomut	0.094		
Q	Residence quotient	-0.102		
C_s	Number of contacts (/10)	0.004	0.037	0.004
C_{p3}	% of contacts in 3 mi	-0.006		
G	Gender (1=male)	0.008	0.072	0.008
$log(T_{mt})$	Meeting duration	0.114		

Chapter 8

Summary

The last half century has seen an evolution of transportation models that have tried to make sense of the demand for travel. These models have been key in making informed decisions about long term changes in infrastructure and policy that are needed to accommodate future demand. For a long time the approach taken by transportation modelers has been the four step planning process which spatially aggregates decision makers and analyze zone to zone demand separated by purpose and time of day. As part of this approach, many planning organizations still match home and work locations in the trip distribution step using a gravity model. In this approach trips for work purposes are distributed to different zones not much differently from shopping trips. The model overlooks many of the complexities behind job finding.

This dissertation documents the different roles the job search process and social contacts in particular affect the home-work matching. In several, relatively independent but related chapters, we have explored the co-location patterns that are present in home and work locations, the changes over time of job search methods, what types of people use which methods, and the relationships between the search methods and commute as well as relocation. An agent based model that explicitly considers the matching process has also been proposed and tested for the Twin Cities area. In addition, the role of contacts in social activity travel and time allocation has also been explored.

The findings suggest that contacts play a role in work-home co-location. The empirical results from the data collected also showed that job search that used the internet resulted in longer home to work distances as well as faster relocation to a new location. Variables such as size of social network were also important in which methods people were successful to find employment. The results overall highlighted the complexity of the process. The proposed agent based simulation model was able to replicate much of the aggregate distribution of jobs. The results from this model also suggested that job search very close to the neighborhood maybe either significantly more intensive, or that considerable relocation occurred to areas very close to the work place after a job is found. Given better data on jobs and employees, this model can be further developed to extract better matches between home and work.

The fact that contacts can play different roles under different circumstances makes it difficult to generate an all encompassing theory of social networks in travel choices. But the results here underline their importance for both work and non-work trips further highlighting the need to consider them and other search methods explicitly as more nuanced travel models are developed.

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Appendix A

Appendix

A.1 Recruitment postcard

Figure A.1: Recruitment postcard

A.2 Web survey

Your Job

Are you currently employed?

- No
- Yes

How many jobs do you currently have?

Job title (If you have more than one job, please answer the following questions for the job that earns you the highest income)

Which of the following best describes your position?

- Technical
- Managerial
- Adminstrative
- Professional
- Service
- Manufacturing

Job location

Address/Closest cross street

City

State

When did you start working at your primary employer? (Month/Year)

/

On average how many hours do you work per week?

Has your job site moved since you started working there?

- No
- Yes

If yes, please provide location:

Closest cross street

City

ZIP Code

How did you find your primary job?

Through formal search using... (please select the method you used from the list below)

- Internet search
- Newspaper ads
- Radio ads
- TV ads
- Recruiter/Agency
- Temp to hire
- Job fair
- Trade journals
- Walk In/Resume Mailing
- Other (please specify)

Through someone I know who is... (please select how this person is related to you from the list below)

- A friend
- A friend of a friend
- A colleague (from my last job)
- A colleague (from a job previous to my last job)
- A family member/relative
- A neighbor
- Other (please specify)

Next

Please answer the following questions about the contact who helped you find your job

How often do you talk to this person by phone or internet chat?

- ○ More than once a week
- ○ Once a week
- ○ About once every two weeks
- ○ About once a month
- ○ Rarely
- ○ Never

How often do you meet this person **socially (non-work related activities)**?

- ○ More than once a week
- ○ Once a week
- ○ About once every two weeks
- ○ About once a month
- ○ Rarely
- ○ Never

How often do you meet this person **professionally (work or professional institution related activities)**?

- ○ More than once a week
- ○ Once a week
- ○ About once every two weeks
- ○ About once a month
- ○ Rarely
- ○ Never

How often do you keep in touch via email, mail or text?

- ○ More than once a week
- ○ Once a week
- ○ About once every two weeks
- ○ About once a month
- ○ Rarely
- ○ Never

How long have you known this person?

[ ] Years [ ] Months

Do you know where this person lives?

- ○ No
- ○ Yes

If yes, please provide the following information

Closest cross street [ ]

City [ ]

State [ ]

At the time they helped you find your job, where did this person work?

- ○ Same place as where you now work
- ○ In a related industry
- ○ In a different industry
- ○ Retired
- ○ Unemployed
- ○ Don't know

How did they know of the job opportunity?

[ ]

The person who helped you find the job is...

- ○ Male
- ○ Female

How old is this person?

[ ]

Next

Job search methods

How often do you use the internet?

- ○ Daily
- ○ A few times a week
- ○ A few times a month
- ○ Rarely
- ○ Never

If used daily, how many hours do you spend on the internet per day [ ]

Before finding your current job, what methods did you primarily use to search for work? [**Check all that apply**]

- ☐ Internet
- ☐ Newspaper
- ☐ Radio/TV
- ☐ Recruiter/Agency
- ☐ Friends
- ☐ Friends of friends
- ☐ Neighbors
- ☐ Family members/Relatives
- ☐ Other (please specify): [ ]

At the time you took this job, were you employed?

- ○ No
- ○ Yes

If yes, please provide location

Closest cross streets [ ]
City [ ]
State [ ]

At the time you took your current job, did you have other offers that you rejected?

- ○ No
- ○ Yes

If yes, how many other offers did you have?

[ ]

If yes, please give locations for the top two offers you did not take:

Offer 1 location	Closest cross streets	[ ]
	City	[ ]
	State	[ ]
Offer 2 location	Closest cross streets	[ ]
	City	[ ]
	State	[ ]

What were the top two reasons you chose your current job among the competing offers?

Reason 1	[ ]
Reason 2	[ ]

Including your current job, how many full time jobs have you had since you turned 21?

[ ]

What would be your primary method to look for a job if you were job searching today?

- ○ Internet
- ○ Newspaper
- ○ Radio/TV
- ○ Recruiter/Agency
- ○ Friends /People I know
- ○ Family members/Relatives
- ○ Neighbors
- ○ Other (please specify): [ ]

How many of your co-workers at your current job do you consider close friends?

[ ]

How many of your closest friends have been your co-workers?

[ ]

Next

Residence

Where do you currently live **(this is where we will mail the survey prizes)**?

Street address: ________

City ________ ZIP Code ________

When did you move to this location?

Month ________ Year ________

Dwelling type

- ○ Single family house
- ○ Duplex
- ○ Townhouse
- ○ Condo/Apartment
- ○ Trailer home

Do you currently

- ○ Rent
- ○ Own

How many times have you moved since you turned 21?

____

What was your last address before you moved to your current residence?

Closest cross streets: ________

City ________ ZIP Code ________

At your previous address did you...

- ○ Rent
- ○ Own

What are the top three reasons you chose your current neighborhood?

Reason 1 [select from list]

Reason 2 [select from list]

Reason 3 [select from list]

Other (please specify) ________

At the time you decided on your current residence, how many other potential homes were you seriously considering?

____

Please enter the city and state for the top two other locations you were considering:

Location 1 — City ________ State ________

Location 2 — City ________ State ________

When looking for your current home, did you limit your search to homes that were within a particular travel time to your work?

- ○ No
- ○ Yes

If yes, what was the maximum travel time you were willing to travel? ________ Minutes

[Next]

Residence

Are there people that live within two blocks of your house that work where you work?

- No
- Yes

If you answered yes, how well do you know them?

- Close friends
- Casual friends, we talk regularly
- At a distance, we say hello if we ran into each other
- We have seen each other at work
- I am not sure if he/she know we work together

If you answered yes, did any of these people advise you to choose your current neighborhood before you moved?

- No, but I advised them to choose this neighborhood
- No, it is purely accidental that we live in the same area
- No, but I was aware they lived here before I relocated to this area
- No, but they were aware I lived here before they relocated to this area
- Yes

How many of your neighbors do you know? (please give number of households)

How many of your neighbors are you friends with? (please give number of households)

Did you choose your home location so that travel time to work was acceptable to all working adults in your household?

- No, travel time to work was not a major consideration
- Yes, so that it was acceptable to me
- Yes, so that it was acceptable to another household member
- Yes, we tried to balance everyone's work travel time

If you were to move today what are the top three criteria you would use to choose a neighborhood?

Reason 1 select from list

Reason 2 select from list

Reason 3 select from list

Other(please specify)

Next

Friends and Family

How many friends and family members do you have that you keep in touch with (by phone, email, internet chat, face to face etc.) **at least twice a month that don't live in the same house as you**?

How many of these live...

outside the United States?
somewhere in the US **outside MN?**
within the state of Minnesota ?
within 10 miles of where you live?
within 3 miles of where you live?
within in three blocks of where you live?

How many friends and family members do you have that you **meet in person at least twice a month?**

How many of your **closest friends** did you meet at...

Work
Church
Child's school
Neighborhood
Your school
On the internet
Social culbs (e.g. Book clubs)
Grew up together

Next

Scheduled Meetings with Others

Please list **all scheduled meetings** you had in **the last 7 days outside of your work location**. *These include all meetings with family, friends, get togethers, parties, civic engagements, meetings for personal/home related tasks, first time meetings etc.*

Meeting	How is the person you met related to you?	Meeting time	Meeting duration (Minutes)	Day	Location description	Meeting address **(intersection or near by landmark)**	City	State	I travelled by	Meeting purpose	You usually communicate by :	Meeting sheduled by:
Example	Close friend/s	16:00	90	Select	Coffee Shop	66th and France	Edina	MN	Car	Leisure	Email	Phone
1	select			Select	Select				Select	Select	Select	Select
2	select			Select	Select				Select	Select	Select	Select
3	select			Select	Select				Select	Select	Select	Select
4	select			Select	Select				Select	Select	Select	Select
5	select			Select	Select				Select	Select	Select	Select
6	select			Select	Select				Select	Select	Select	Select

Would you say this number of meetings over a 7 day period is typical for you?

- ○ Yes
- ○ No, I usually have fewer meetings
- ○ No, I usually have more meetings

Approximately how many such meetings do you have in a 7 day period?

Did you have any cancelled meetings in the last 7 days? If so, how many?

Do you have more meetings to enter?

- ○ Yes
- ○ No

Next

Getting Around Town

How do you usually get to work?

- ◯ Walk ◯ Bicycle ◯ Drive alone
- ◯ Carpool ◯ Bus ◯ Light rail
- ◯ Taxi/Shuttle ◯ Motorcycle/Moped

What time do you usually leave home to go to work? (hh:mm)

[ ]

How long does your trip from home to work take?

[ ] minutes

Do you have to be at work at a fixed time?

- ◯ No
- ◯ Yes

If yes, what time do you **have to be** at work? (hh:mm) [ ]

How would you describe the traffic conditions on your trip to work?

- ◯ No congestion ◯ Fair
- ◯ Congested ◯ Very congested

How would you rate your commute experience on your trip to work?

- ◯ Unbearable ◯ Bad ◯ Tolerable/fair
- ◯ Good ◯ Excellent

How long would the same trip from home to work take on a Sunday morning?

[ ] Minutes

Where do you get travel information regarding your work commute?

- ◯ Personal experience ◯ Internet
- ◯ TV ◯ Radio
- ◯ Co-workers ◯ Newspaper
- ◯ I don't look for information regarding my commute.

How do you primarily get around town for non work trips?

- ◯ Walk ◯ Bicycle ◯ Drive alone
- ◯ Carpool ◯ Bus ◯ Light rail
- ◯ Taxi/Shuttle ◯ Motorcycle/Moped

Next

Demographic Information

You are...

- ◯ Male
- ◯ Female

Age

[ ]

What is the highest level of education that you have completed?

- ◯ 11th grade or less
- ◯ High school graduate
- ◯ Associate degree
- ◯ Bachelors degree
- ◯ Masters degree
- ◯ Doctoral degree

Do you ever work from home instead of travelling to your usual work place?

- ◯ No
- ◯ Yes

If you telecommute, how many days out of the week do you work from home instead of traveling to work?

[ ]

If you telecommute, on the days that you travel to work, how many hours do you also work at home?

[ ]

If you telecommute, how many hours do you work from home when you do not travel to work?

[ ]

How many household members, including you, live in your household? [ ]

Number of adults in household: [ ]

Number of children under 6 in household: [ ]

Number of children 6-12 in household [ ]

Number of children 13-17 in household [ ]

Number of students in household: [ ]

Number of employed people in household: [ ]

How many motor vehicles are available to members of your household?
This should include all cars, trucks, vans, motorcycles, and recreational vehicles:

[ ]

How many mobile phones do you have?

[ ]

My Internet service at home is...

- ◯ Telephone dial up service
- ◯ DSL
- ◯ Cable Modem
- ◯ Community wireless
- ◯ I don't have one

What is your household income? (Please enter to the nearest 5000 dollars. e.g. 55000)

[ ]

What is your race?

- ◯ Caucasian
- ◯ Black
- ◯ Other
- ◯ Latino
- ◯ Asian
- ◯ Native American
- ◯ Mixed

Please choose where you would like your $5.00 gift card to be from:

[select from list]

[Finish and Submit]