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Home, Job and Space

Mapping and Modeling the Labor Market

GEOGRAFISKA REGIONSTUDIER NR. 72

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Abstract
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How does space affect individuals' outcome on the labor market? And how do we measure it? Beyond the notion of the labor market as a system of supply and demand, lays a society of individuals and workplaces, whose relationships are undeniably complex. This thesis aims to shed some new light on how to investigate and analyze the complex labor market relationships from a spatial perspective.

In this thesis, five self-contained articles describe the spatial relationship between individuals and workplaces. In the first article, the official delineation of local labor market areas is tested against the delineation of labor markets for different subgroups. Differences in the regionalization are discussed from the subgroups' and municipals' perspective.

In the second article, two sources of bias in the computation of local labor market areas, and suggestions how to reduce them, are presented.

In the third article the spatial mismatch hypothesis is tested and confirmed on a refugee population in Sweden.

In articles four and five, a new model for the estimation of job accessibility is introduced and evaluated. The model, ELMO, is created to answer to the need for a new accessibility measure to be used in spatial mismatch related research. The usability of the model is validated through empirical tests, were the ELMO-model excels in comparison to the accessibility models it is tested against.

Keywords: GIS, ELMO, Estimated Labor Market Outcome, Estimated Labour Market Outcome, Accessibility, Access, Job Accessibility, Place, Employment, Unemployment, Labour, Labor, Labor Market, Labour Market, Topology, Local Labour Market Area, Modelling, Modeling, Spatial Modelling, Spatial Modeling, Spatial Mismatch, SMH, Mismatch, Commuting, Regionalization, Geography, Population Geography, Economic Geography, Time-geography, Space

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The attached articles

Article I
Östh J. Homogeneous Regions and Heterogeneous Populations
Creating and Analyzing Labor Market Regions for Subgroups in Sweden

Article II
Östh J. Rethinking the Computation of Labor Market Regions
Consequences of Population Selection Bias and Suggested Solutions

Article III
Åslund O. Östh J. Zenou Y. How important is access to jobs?
Old question – improved answer

Article IV
Östh J. Modeling Job Accessibility
Introducing a new model of potential job accessibility

Article V
Östh J. Job Accessibility and Space
Examining the functionality of job access models used in mismatch related hypotheses

Contents

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Home, Job and Space

Historically, the match between supply and demand for many of the needed goods where met within the bounds of the marketplace. In contemporary society, the marketplace has been transformed into the supermarket, wherein a wide range of goods are supplied to and demanded by the customers. Common to both of these markets is that they are manifested within the bounds of an arena in which the match between supply and demand is met. The labor market is often depicted in a similar fashion. However, the match between supply and demand for labor, takes place within the bounds of a much greater area; the local labor market area. The area encompasses both core and peripheral parts of the labor market. Consequently, inhabitants in different parts of the labor market area have not got equal opportunities to access various parts of the labor market. The key difference between the supermarket and the labor market is that space is a much more important denominator for the outcome on the labor market. Still, in many studies, the county's, region's or even country's job growth or job loss figures are used to predict the labor market outcome of the individual. If the importance of space is decreased in such a fashion, the similarities between the labor market and the supermarket increase, and mechanisms of job loss figures will have more in common with figures describing shortage of milk in the supermarket, than the actual process of matching supply of and demand for labor.

However, among geographers, the importance of space, in systems of supply and demand, has been discussed for a long time. An early contribution to the matter was produced by Torsten Hägerstrand in his PhD-thesis (Hägerstrand 1953). In the introductory parts of his thesis, Hägerstrand discusses the motives and prerequisites for spread of innovations, by analyzing the patterns of spread and networking in a rural part of Sweden. An important observation regarding the spread of innovations is that it can not be depicted if the geographical perspective is left out. This is argued since the spread of innovations occur in a radial fashion from locations inhabited by the pioneer users. This also implies that living close to a pioneer user increases the probability to experience and accept the use of an invention.

The observed patterns of innovation spread constitute the basis for the construction of models in Hägerstrand's thesis. In his modeling approach, Hägerstrand tries to replicate the empirically observed pattern of spread of innovations through the inclusion of various possible influential factors. The factors are included stepwise in increasingly complex models in order to illustrate the effect of using different factors. In the first model to be tested, Hägerstrand tests a setup where space is considered as unimportant; the information about the innovation is distributed publicly through radio and the innovation is accepted and used if the listener receives the message. The model produces a randomly distributed spatial pattern which is quite different from the observed pattern of innovation spread. The result clearly indicates that space needs further attention. In remaining modeling, spread of innovation is alleged to occur in relation to proximity to the assigned pioneer users. The results from these models all point towards greater similarities to actual patterns of innovation spread, if compared to the random spread model depicted above.

Hägerstrand shows in his thesis that many societal issues must be studied and modeled from an *in situ* perspective to gain credibility. The *in situ* perspective involves the acknowledgement of every studied individual's or object's location and relative position to others. Consequently, Hägerstrand's most renowned theme of research, the field of time-geography, deals with the highly complex relationships between individuals as a result of their placement in space and time, see for instance (Hägerstrand 1970).

Though the scientific incentive is somewhat different in this thesis, the setting of the models and methodological reasoning expressed by Hägerstrand are used as cornerstones, especially in the development of the model building conducted in articles four and five in this thesis. Since the research aim in this thesis is directed towards the modeling and analyzing of job accessibility, a different range of factors and research questions is used. Furthermore, in contrast to the study of innovation spread, job accessibility can not be empirically determined. The difference lays in the fact that the development of spread can be monitored over time while accessibility only vaguely, but never definitely, can be described. Time-geography has however assisted in the creation of a framework for the measurements of accessibility through its discussion of individuals' prisms. The various constraints determining the bounds of the prism constitute the basis of understanding different individuals' ability to participate on the labor market.

This thesis will in many ways follow in Hägerstrand's footsteps. Just as Hägerstrand assumed that the probability of adopting an innovation is strongly influenced by the geographical context, I will focus on the way the labor-market outcome of individuals is shaped by their geographical access to job opportunities. In order to analyze the mechanism of spatial innovation diffusion, Hägerstrand used a manually implemented mathematical model that allowed for a complex spatial interaction between individuals. In the same way, my way of modeling job accessibility is designed to account for the complex interaction between individuals when they compete for jobs in a spatial context.

Moreover, the data on the location of jobs and dwellings that I will use can be seen as the result of an idea launched by Hägerstrand in the late 1950s on how Swedish register data could be geo-referenced.

Undoubtedly, Hägerstrand has served as an important source of inspiration for the scientific work in this thesis, and will undoubtedly continue to do so in works yet to come.

Aims and questions

In all, five articles are included in this thesis and the all-embracing theme in all of the articles is the relationship between work and workers. This relationship is predominately studied from a spatial perspective, a perspective that can be perceived as something both beneficiary and hampering for the functionality of the labor market, depending on what view of the labor market is used. Space can be perceived as something beneficiary from a labor market region perspective where a larger, populous and job rich area determines the amount of possible matches between the individual's skill and the workplace's need for different types of expertise. The hampering side of space is factual viewing the labor market from the worker's perspective since the worker's access to labor is to a large degree dependent on proximity to jobs, and consequently space, or greater distances, is viewed as a job match restricting factor.

Two of the articles focus on the regional extent of labor market regions. In these two articles, the effect of viewing space as something beneficiary for the labor market functionality is analyzed. In the remaining three articles, the opposite view of space and labor market functionality is used. The latter articles explore the effects of job competition for individual's jobs accessibility in spatially constrained labor markets. Consequently, the overall important question asked through out the thesis is, how does space affects outcome on the labor market?

In the first article, the delineation of labor market regions in Sweden is analyzed. There is currently a well-defined and commonly used method for the delineation of regions, coupling municipals with a common labor market core, defined by the cross municipal border commuting rate. The key questions in this article are, to what extent do these regions represent the commuting pattern of different subgroups, and does the commuting behavior of subgroups vary in various types of municipals? To answer these questions the cross commuting rate of different subgroups of the entire Swedish workforce in the year 2000 is used. The aim of the study is to show that policy decisions based on the spatial extent of labor market regions is risky, unless the commuting pattern between subgroups and within different types of municipals is considered further. The theories and methodologies used in this article are described under the section "the concept of local labor market areas".

In the second article, some biases in the computation of labor market regions are captured, and solutions suggested. This article is a freestanding continuation of the first article. In the article, two sources of population selection bias are addressed, of which both types of errors are frequent enough to alter the regionalization of the contemporary used labor market regions. The key questions in this article are, what types of population selection bias may risk the computation of labor market regions, and how can population selection bias in the computation of labor market regions be minimized? The questions are answered using data of the Swedish working population in the year 2002. The theories and methodologies used in this article are described under the section "the concept of labor market regions".

In the third article, the spatial mismatch hypothesis is used to analyze the labor market outcome of immigrants. The hypothesis used is described further in the section "The spatial mismatch hypothesis". This article is different from the previous two since the aim of the study is directed towards the individual's labor market outcome, rather than the labor market region. The major question in this article search to answer whether the placement of immigrants in the early 90ies led to spatial mismatch i.e. did placing immigrants in locations that hampered their future participation on the labor market? The question is answered using two sets of populations for the years 1990, 1991 and 1999, of which one contained immigrants arriving during the years 1990 and 1991, while the other population was compiled as a random selection population for comparison.

Articles four and five address a need for the development of an improved measure of job accessibility. In the mismatch related literature, described in sections "The spatial mismatch hypothesis", "Hypotheses on gender, labor and space" and "Spatial arrangement of work opportunities", poor measures of accessibility are commonly being used to proxy availability to employment. The aim of articles four and five is to introduce a model for the computation of accessibility that can be beneficiary for use in the mismatch literature. In the fourth article, the new model, ELMO, is introduced, discussed and tested from a theoretical standpoint. In the fifth article, the ELMO-model is tested against commonly used measures of accessibility. The key question in the latter article is to test whether the new model excels in mismatch related studies when compared to commonly used measures. The empirical tests in article five were made using all available jobs and the entire work-able population in three municipals during 1997.

To assist reading the articles in this thesis, a number of introductory sections depicting the used hypotheses and presenting some of the key methodologies are available in this kappa[1]. The kappa is arranged as follows; first, the hypotheses and theories used in this thesis are presented. Secondly, com-

[1] Kappa refers to the Swedish word used to describe an introductory text summarizing the works of a thesis.

monly used methodologies for the computation of accessibility are presented and discussed. Thirdly, theory, statistical notation and means for the computation of the ELMO-model are described. Fourthly, the data material used in the articles is presented. Finally, the five articles in this thesis are summarized.

Theories and hypotheses

In this section, theories and hypotheses used in the thesis are introduced. The introduction follows the arrangement of articles in this thesis, starting with the theories accompanying the delineation of labor market regions (articles one and two), followed by the theories and hypotheses used in articles three to five (focusing on labor market mismatch).

The concept of local labor market areas

The delineation of local labor market areas constitutes a vital key not only to the understanding of the labor markets functionality on local and regional level, but also in the process of reproducing the perception of belonging to a region. For these reasons, the grouping of various types of administrative regions into a greater area is a delicate task, both producing and reproducing the perception of functionality and belonging among citizens and institutions, both public and private. The importance of recognizing the entire region as the region is currently evident in contemporary Swedish politics, where a trial period of congestion taxes in the central-most parts of Stockholm has been tested since late August 2005. Contemporary to the Swedish general elections, in September 2006, the citizens of Stockholm municipal had the possibility to say yes or no to a prolongation of the congestion taxes. Other municipals in the Stockholm labor market region were however not asked for their opinion on the congestion taxes. This led to a heated debate about environmental issues, commuting costs but perhaps even more about regional belonging and democracy. The poll-result revealed that the citizens of Stockholm municipal were in favor of the congestion taxes while citizens in surrounding municipals were not, a circumstance that has not assisted to calm the debate. Beside reasons of democracy and belonging, the more typical and perhaps even more important incitement for the creation of labor market regions lays in the legitimacy of greater investments in infrastructure, healthcare and higher education. Typically, questions concerning greater investments strive to solve future needs in the labor market region; such as, what parts of the region would benefit most from the creation of a tram-line, or an industrial harbor or an airport, and what location would benefit the region as a whole?

Questions like these, point to the importance of using labor market regions that correspond to the citizens' perception of the regional extent and which can be used as an instrument in political decision-making, beneficial to a region more valid than the imaginary. Therefore, in the process of creating labor market regions, it is important to remember that labor market regions both could and should be constructed in different ways in different areas in order to gain representability, since there is no natural best way for the creation of labor market regions (Coombes 1995). Though the approaches used in the creation process of labor market regions are different, the delineation however often stem from theoretical perspectives on the functionality of labor and space. Various theoretical perspectives on the classification of labor market are presented in *Figure 1*.

The classification of theoretical perspectives is split in two major groups, the homogeneous and the heterogeneous classification of labor market regions (Laan van der 1992; Laan van der and Schalke 2001). The classification represents theories that stress the existence of submarkets of types of labor (heterogeneity), and theories that perceive the market as a whole entity (homogeneity).

Heterogeneity perspectives state that agglomeration of labor is possible only to some extent; this is because each submarket is characterized by a different size and shape. The reasons behind the labor market heterogeneity are theoretically motivated either by societal structures, such as institutional framework, power, alignment etc (Cook 1983), or by materialistic relations between labor and capital (Harvey 1982; Scott 1985).

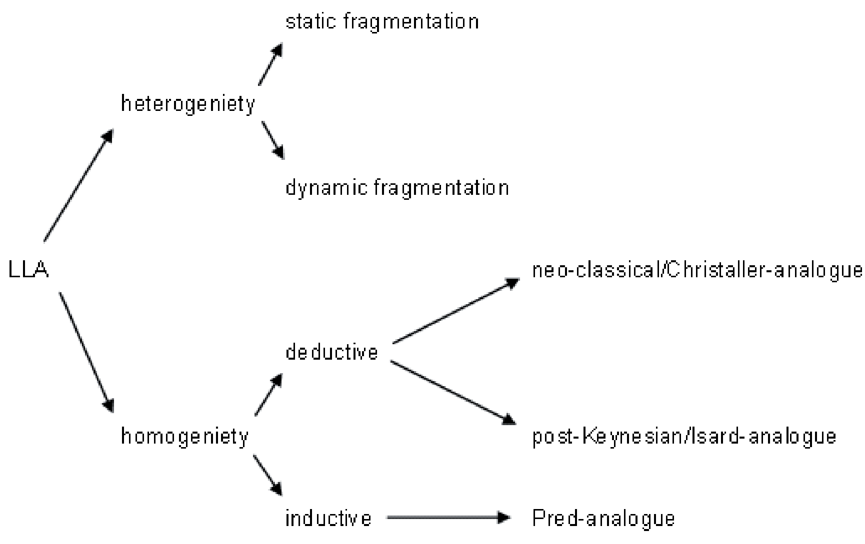

Figure 1. Theoretical perspectives on the classification of local labor market areas (Laan van der and Schalke 2001).

Heterogeneous perspectives can be arranged as being either static fragmented or dynamic fragmented (Laan van der and Schalke 2001). Static fragmentation is an approach where gender, ethnicity, educational level etc is perceived as being responsible for labor market fragmentations. The static grouping of labor market hence uses predefined groups as an instrument of delineation. Contrary to the static fragmentation theory, using the dynamic fragmentation approach means that the subgroups are not predefined (static) but produced as a result of empirical analyses. Segments or subgroups on the labor market wherein labor mobility is predominately endogenous, are used to denote submarkets on a fragmented labor market (Lindgren 2006).

The homogeneity perspective on the labor market does not deny the existence of heterogeneity on the labor market however, investment decisions, healthcare strategies etc can not make use of a regionalization process that is heterogeneous. For this reasons regions must be comprehensible and for most times static. The regions are therefore constituted on the grounds of majority behavior, being the spatial container wherein the bulk of labor takes place (Smart 1974). Labor market regions, constructed using a homogeneity approach, are as a result composed of combinations of, most often, smaller administrative regions that together make up regions where the majority of the regional supply and demand takes place.

Homogenous regions can either be constructed using a deductive or an inductive approach. The deductive approach is in turn divided into a neo-classical perspective and a post-Keynesian perspective. The neo-classical perspective uses a Christaller-analogical hierarchical view on the labor market. The arrangement of regions follows a hierarchical logic, where some labor-related functions are available almost everywhere, while others serve a greater area. The served areas become attached to the serving areas, creating a hierarchy of areas that can be perceived of as a labor market region. The other deductive approach in the creation of labor market regions can be derived using a post-Keynesian perspective. This perspective involves the delineation of regions by analyzing the specialization of production on the labor market. Specialization expressed as agglomeration of production and reproduction can be used to describe the labor market in terms of regions.

Finally, the inductive approach to the delineation of labor market regions differs from the deductive approaches since it uses no predetermined and categorized areas of labor. The inductive approach demarcates regions as a result of their actual pattern of interaction. These regions, often referred to as functional regions, predominately use commuting rates in-between locations as an instrument in the delineation-process. The constructed regions therefore aim to mimic actual mobility on the labor market. (Laan van der and Schalke 2001)

The delineation of labor market areas in Sweden

Currently two delineations of labor market regions are used in Sweden, SCB's (Statistics Sweden) LA and NUTEK's (Swedish Agency for Economic and Regional Growth) FA. Both agencies' regionalizations are made using a homogeneity inductive approach. The SCB approach involves analyzing the share of outward-commuters from each Swedish municipal. Municipals that have a greater share than 20% of its habitual population commuting to other municipals, and or municipals that have at least 7.5% of their outward-commuting directed to a single municipal, are registered as belonging to a labor market region that has its core in another municipal. Core-municipals are identified as the municipals that do not have large enough outward-commuting (Carlsson, Johansson, Persson and Tegsjö 1993; SCB 2006). The NUTEK- delineation of labor market regions is similar to but more complex than the SCB-regionalization. The reason both regionalization approaches are used in Sweden simultaneously is that the SCB-approach reflects the contemporary regional delineation, while the NUTEK-regionalization aims at delineating labor market regions that not only reflect the current labor market regions, but the probable regionalization of tomorrow as well. NUTEK has adopted six steps in the computation of labor market regions, wherein their relative importance for the delineation process follows the enumeration-order (NUTEK 2005):

1. Statistics on cross municipal-border commuting 2003
2. Trends in commuting flows between municipals over time
3. Combined flows of commuting between municipals
4. Absolute quantity of commuters
5. Investments and or political decisions that are presumed to have an impact on future commuting behavior
6. Other structural or behavioral changes that might change regional belonging

As mentioned earlier, both methods of regionalization can be referred to as homogenous inductive. Homogenous since both approaches assume that the labor market, for practical reasons, must be viewed as a whole and inductive since neither of the approaches use predefined centers in their delineation of labor market regions.

The use of labor market regions in this thesis

Two of the articles available in this thesis (first and second article) make use of the regionalization of labor market regions. In the first article, the homogenous inductive perspective on regionalization is contrasted by the use of heterogonous and statically fragmented population subgroups. The combination of these two perspectives aims at showing that the labor market regions of various subgroups alter significantly and that certain types of municipals either reduce or increase the differences between subgroups systematically.

In the second article, two sources of population selection bias are presented. The effects of using a biased population, regularly used in the delineation process, is the delineation of labor market regions that do not agree with the regions delineated using bias-corrected populations.

The outcome of accessibility

Articles three, four and five in this thesis base their theoretical reasoning on different hypotheses aiming to depict the individual's labor market outcome as a result of societal structures. These hypotheses differ from the labor market region theories due to their focus on the individual's access to labor rather than delineation of regions of labor.

The time-geographical perspective offers an a-theoretical perspective of the relationship between space and time (Lenntorp 1999; Hägerstrand 2001). As such it represents a vital set of tools for the creation and evaluation of hypotheses claiming a detectable and explainable outcome resulting from the estimated accessibility. Due to the labor market oriented nature of this thesis, the theories and hypotheses of interest are primarily aiming at describing the relationship between access to jobs and the outcome on the labor market as a consequence of the access. The core-theme of these hypotheses is that the outcome on the labor market is not random, but an effect of societal structures dictating the labor market conditions and, but to various extent, the spatial pattern of the region. In *Figure 2*, the relationships are illustrated further. The two groups of actors in the figure are the demanders, being the potential workers, and the suppliers, being the potential employers. The hypothesized labor market outcome is a result of the demanders' habitual location and individual characteristics in reference to the workplaces' location and characteristics.

In short, the habitual location of individuals affects attractivity on the labor market through degree of proximity to sources of labor and competition for jobs, as do access to transportation. The societal perception of the habitual location is another factor that can stigmatize or assist demanders' search for jobs. Individual characteristics such as educational level or experience denoting skill, and or discriminating factors based on issues such as ethnicity, gender or looks may influence labor market attractivity. From the supplier perspective the similar pattern is detectable; the location of a workplace may be distant or close to the workforce, being or not being easily accessible with various types of transportation, and or being located in areas of different societal perception. From the workplace characteristics perspective, the attractivity of offered jobs depend on the job characteristics such as skill-demand, career-opportunities, salary etc.

In the midst of the figure, space is positioned as the mediator of labor market functionality. An issue of importance in the labor market outcome hypotheses is the notion that spatial factors control aspects such as job-search behavior and intensity, labor market information and commutability.

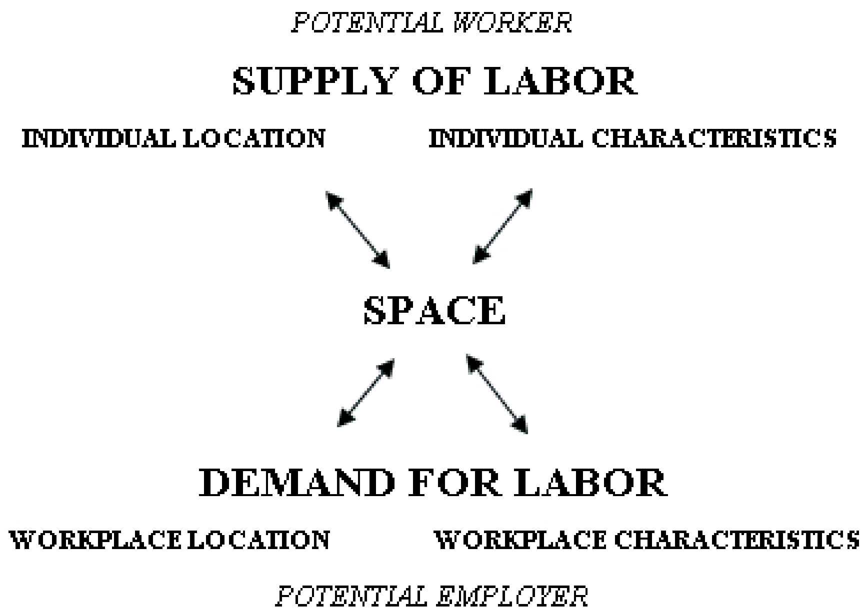

Figure 2. The function of space in a labor market setting of supply and demand

In the following section various commonly used hypotheses will be discussed shortly. The discussion should not be understood as an all-embracing presentation of all hypotheses used to describe the spatial relationships between demand and supply in labor market oriented studies, but the intension is to present a guide to the general ideas and theories behind the most commonly used hypotheses involving supply and demand from a spatial perspective. In a review article on the use of space in labor market studies by (Fernandez and Su 2004), the relationship between space and labor market outcome has resulted in a grouping of hypotheses into three groups, based on their similarities. The three groups are represented by (i) the spatial mismatch hypothesis and other closely related hypotheses, (ii) gender-related hypotheses and finally what the authors refer to as (iii) theories of spatial agglomeration of companies. Since the prime interest in this thesis is directed towards the individual's labor market situation, groups (i) and (ii) are of prime interest. Certain hypothetical elements in group (iii) are interesting for the individual's labor market output as well, why all three groups will be presented in accordance to their importance in relation to their use in this thesis.

The spatial mismatch hypothesis

Perhaps most influential of all hypotheses dealing with the matching process between supply and demand of labor, the spatial mismatch hypothesis (SMH) was introduced to address the escalating labor market problems befalling the Afro-American inner-city population (Kain 1968). Kain noticed that the suburbanization of jobs, from the inner city districts, increased over time while the migration of African-American from the inner city region remained low. This meant that the separation of work from the minority groups increased. It is however important to postulate that beside reasons of ethnicity, issues relating to, or converging with, class-belonging affects individuals similarly (Wilson 1990). The prime reason for the increasing separation of minorities and work was, and still is, the housing discrimination, see for instance (Massey and Denton 1993). The increasing distance between home and job, inherit to minority groups, theoretically implies that (i) the job-search efficiency decreases since information about job-offerings become less available. (ii) The potential commuters may be increasingly reluctant to accept job openings due to increase in commuting cost and commuting time. (iii) Potential employers might be increasingly reluctant to hire distant workers, since traffic frictions such as congestion may hamper the workers possibility to come to work on time. (Wasmer and Zenou 2002; Zenou 2002; Smith and Zenou 2003; Åslund, Östh and Zenou 2006)

Empirical articles on spatial mismatch suggest, in a majority of the studies, that minority groups suffer from labor market disadvantages related to the spatial mismatch between place/neighborhood of residence and work, see for instance (Gabriel and Rosenthal 1996; Holloway 1996; McLafferty and Preston 1997; Rogers 1997; Raphael 1998). However, in a significant number of articles, the empirical results do not validate the hypothesis, and or express criticism towards the methods used to test the hypothesis, see for instance (Taylor 1995; Cook and Ross 1999; DeRango 2001; Perle, Bauder and Beckett 2002). The issues of critique are primarily directed towards the measurement of accessibility. The accessibility measures are in most articles constituted by commuting time, commuting distance or distance from predefined sites within the urban landscape (such as the suburbs or the city center). These kinds of proxies of accessibility are problematic to use since their use assumes that the commuting length or time is directly associated with an individual's access to jobs. As (DeRango 2001) points out, the logics behind this assumption is questionable. An individual may choose to reside in proximity to amenities other than jobs, indicating that a plain cost-benefit modeling of housing is not applicable. Other factors than choice affects the commuting outcome as well. The spatial separation of minorities and work do hypothetically lead to prolonged commutes, however if the spatial separation reaches a certain threshold, people might chose not to commute, resulting in high unemployment and a few individuals commuting for short distances.

The problem of using commuting distances to denote accessibility has partially been solved by using the commuting pattern of individuals whose place of residence is determined by others than them selves, i.e. not endogenous. For this reason individuals, such as youth residing at their parents' homes, can be used to reduce this problem, and has been used in several studies, see for instance (Ihlanfeldt 1988; Ihlanfeldt and Sjoquist 1989; Ihlanfeldt and Sjoquist 1990). Article three in this thesis uses a population based on refugees to reduce bias of endogenous choice (Åslund, Östh and Zenou 2006). However, problems related to the measurement of accessibility remain the key reason to why there is an ongoing debate concerning the validity of the hypothesis. The development of the ELMO-model is a direct response to the need for a creation of an improved measure of accessibility.

Three excellent reviews covering a large part of the vast amount of research done on spatial mismatch can be recommended for further reading (Kain 1992; Ihlanfeldt and Sjoquist 1998; Preston and McLafferty 1999).

Hypotheses on gender, labor and space

There is scientific consensus in the available literature that women commute shorter distances than do men, though generally more active in reproductive related communication (Hanson and Pratt 1995; Tillberg 2001; Schwanen and Dijst 2002; Clark, Huang and Withers 2003).

There is however no such scientific consensus concerning the reasons for the gendered differences in commuting. According to (Singell and Lillydahl 1986) married women's jobs are considered as less important than their spouses' jobs and as consequence is the searchable space more constrained for women than for men. Another possible and more commonly used interpretation is that women are to a higher extent than men responsible for home-maintenance, child rearing etc; a fact that consequently leads to a more constrained arena of labor. This interpretation is supported by research by, amongst others (Hanson and Hanson 1981; Hanson and Pratt 1988; Hanson and Pratt 1992; Johnston - Anumonwo 1992; Brines 1994; Hanson and Pratt 1995; Dijst 2000). Being responsible for a large share of the domestic responsibilities can however lead to very different labor market outcomes. Being responsible for domestic work means that only few hours are available for paid work, and empirical evidence supports the positive relationship between hours of work and commuting distance suggesting that part-time employed individuals search for employment in proximity to home (Dijst 2000; Schwanen and Dijst 2002)[2]. Beside reasons of part-time employments as an explanation for women's shorter commutes, other factors are important as well. For instance, the gender segmented labor market reinforces differences between men and women through the location of female dominated sectors

[2] Employees with longer than normal work-days do however show a negative relationship between commuting distance and hours worked.

in proximity to the reproductive arena. Jobs in caring and educating sectors are often located “close to home” forming “pink-collar” ghettoes (Hanson and Pratt 1988; Hanson and Pratt 1991). In the US-literature, empirical evidence however suggests that there is an ethnical dimension to the gendered pattern of commuting. Ethnical minority women often commute longer than the majority women (Johnston - Anumonwo 1995; Johnston - Anumonwo 1997; McLafferty and Preston 1997). The empirical results presented in these studies suggest that there are strong links between the spatial mismatch hypothesis and gendered patterns of commuting. The labor market scenery is that of a suburbanization of suitable jobs from the inner-city regions and a concentration of female dominated jobs in proximity to the homes of the majority; a situation which especially hampers minority women being responsible for domestic work and commuting long distances. The evidence is however more valid in the US than in Sweden, since the US urban pattern placing the minority population in the city center and the majority population in suburbia is very different from the situation in the Swedish urban landscape, where the ethnical minority groups predominantly are residing in the suburbs. The mechanisms described above are, however similar in both countries, suggesting that the labor market outcome should be comparable, if the hypotheses prove to be true.

The hypothetical reasoning outlined in this section signifies that not only issues relating to ethnicity, and as a consequence class, denote restrictions in space. While ethnicity and class can be a matter of place just as much as a matter of space, gender is by nature almost always only a matter of space. This is factual since men and women essentially always are represented in equal numbers irrespective of place.

For further readings on the relationship between labor, space and gender, the following texts are recommended (Hanson and Pratt 1995; Turner and Niemeier 1997).

Spatial arrangement of work opportunities

Many geographical and economical viewpoints on the labor market base their perspectives on theories depicting space from a neoclassical or structural angle. As such, the market is often represented by the firms and their ability to attract labor and offset costs by sales. However, the prime interest in this thesis is the labor market outcome from an individual perspective, why the discussion in this section aims at describing hypotheses depicting the individual’s labor market outcome as a result of the spatial pattern of firms.

The greater-sized the labor market, measured in numbers of firms and workers, the greater the possibilities for establishing firms with wider spectra of services, and in analogy, the greater the job opportunities for specialized labor as well (Eðvarðsson, Heikkilä, Johansson, Persson and Stambøl 2000; Malmberg and Korpi 2000). In alignment with this assumption, but different from the spatial mismatch and gender related hypotheses, the hypotheses describing the agglomeration of firms and their labor market outcome view space as something that benefits outcome (Fernandez and Su 2004). A spacious labor market region improves the possibilities for matching of labor and suitable jobs (Wheeler 2001). Agglomeration and/or clustering of firms improve the possibility for individuals with special competence to find employment, which in turn improves productivity and hence increases returns to the stockholders. The importance of individual skill and transfer of knowledge between organizations can not be understated in the analysis of the individual's labor market outcome (Maskell and Malmberg 1999; Hallencreutz 2002; Lundequist 2002; Jansson 2005; Waxell 2005).

The spatial arrangement of employment opportunities is inevitably of uttermost importance for the individual's labor market outcome. If studied in the light of the individuals' ability to match the required skills, the labor market functionality is not only the result of the societal structures determining the rules of supply and demand for different ethnical groups, classes and gender but also the result of the spatial arrangement of firms. In other words, the prerequisites for a time-geographical study lie in the hypothetical depiction of the interaction between work and workers, and as such the three groups of hypotheses presented above form the theoretical platform from which the analyses in this thesis will be conducted.

The concept of potential accessibility

The labor market outcome, viewed from an individual's perspective, is in most hypotheses presented above a result of the individual's access to job. Yet, surprisingly few articles develop an awareness of the definition and use of the accessibility used to signify the labor market outcome. For this reason this section of the thesis is devoted to the definition, development and use of accessibility in the study of labor market outcome.

Accessibility as such is hard to describe in a satisfying way, though the "access"-part of the word offers a possible mean for interpretation. Transformed from a noun into a verb, the action of accessing in combination with the time-geographical perspective of an individual's arena, see (Hägerstrand 1970), provides a clue to a possible reading. Accessible is the world that, still after answering to the capability constraints, coping with the coupling constraints and getting admitted into the domains of authority, is within reach from the individual. Yet, despite this possible explanation, the description lacks a vital part of the description, namely a common representation of the notion of accessibility such as a number, name, scale or shape. Without representation, the question of what accessibility is will repeatedly be repeated, and repeatedly remain unsolved. If the solution to the meaning of accessibility lays in the representation, the question to ask is rather how *we* do measure accessibility, than *what* is accessibility. If any question asked in this thesis can be weighted as more important than all the others this would be the one. The reason why is because hypotheses and theories stating the effects of different access currently are used in debate and policy, which means that the statements of these hypotheses and theories may be contested on grounds of the validity of measures. In short, a valid measure of accessibility makes the world of difference.

So, what is the measure of accessibility? There is no straight forward answer to that question, but a possible starting point for such a answer lays in the division of access-measures into outcome measures and potential measures (Helling 1998). Outcome-measures make use of the individuals' or locations' recorded behavior. To exemplify, the behavior may be recorded as different neighborhoods' various mean commuting distance. The long-distance commuting in neighborhood X will as an effect be contrasted to the short-distance commuting in neighborhood Y. The estimated accessibility will, ceteris paribus, produce a result where the estimated access inherit to the long-distance commuting neighborhood is greater than the estimated accessibility in the short-distance commuting neighborhood. The results will most probably come close to any societal analyses of the differences between neighborhoods. From a potential accessibility perspective, the question is however not answered, since the answer is endogenously connected to the question. Using potential accessibility means separating factors that might bias the answer. In the example used this would mean the separation of place from space, by using the overall mean to depict mobility and by creating an accessibility estimate that describes accessibility if all shared the same pattern of mobility.

In short, the outcome measures produce estimates that closely mimic the actual pattern of individuals. The measures are however contaminated with endogenous factors making interpretations risky. The potential measures produce estimates that on average will fail in comparison to the outcome-measures in terms of mimicking actual patterns; the measures are however not contaminated with endogenous factors. In this thesis, the accessibility to jobs is a key research target, be it on an individual or a municipal level, and for reasons discussed above, outcome measures will, if possible, be replaced with potential measures. The use and construction of potential accessibility measures must also comply with two rules: (i) the measure constructed and used, must be modeled to fit into a tempo-spatial setting agreeable with time-geography; (ii) the measures used and constructed must be beneficial for the studies of the outcome of accessibility.

In the sections to come, potential accessibility measures are discussed further. Initially, a grouping of available measures used to study various types of settings is introduced. The settings represent various scenes of competition affecting accessibility. In the last part of the sections discussing potential accessibility, a new measure of potential accessibility, ELMO, is introduced and discussed.

Potential measures of unconstrained accessibility

Under conditions were individuals' interests in surrounding amenities are not constrained, and were the amenities ability to supply, is not constrained either, competition can be described as unconstrained. Reasons beside straightforward supply and demand may however prevent or promote individuals interest in certain amenities or promote or prevent the ability of amenities to supply. Various restrictions may hamper perfect competition; these restrictions can be distance friction, physical obstacles, individual characteristics or just about any other restriction.

The unconstrained spatial competition scene may be perceived as access to beautiful objects in the environment. Theoretically, there is no saturation to the amount of beauty individuals can consume; similarly there is no limit of supply of beauty. A snowcapped mountain can be viewed repeatedly without losing its beauty. However, distance from the mountain or an individual's ability to see, may hamper the consumption of beauty. Computing unconstrained spatial competition is relatively easy since supply is unrestricted, only the amount of supply relative to the consumer needs to be determined. This can be done by summarizing the amount of supply within the bounds of a spatial shape. A distance deterring function may be used to mimic the friction of distance (Hansen 1959). In equation 1, a regular gravity based model is expressed, where A denotes an individual's access to beautiful things, "beauty" denotes beautiful objects and $f(d_{ij},\beta)$ denotes a function that represent the friction of distance between locations *i* and *j*.

(eq. 1) $$A_i = \sum_{j=1}^{n} beauty_j * f(d_{ij}, \beta)$$

Potential measures of singly constrained accessibility

In circumstances were either supply or demand is restricted, a singly constrained spatial competing scene may be factual. In all essential, singly constrained spatial competition resembles unconstrained spatial competition, with the exception that either supply or demand is limited. A hypothetical example is the relationship between supermarkets and their customers, where there is an "endless" supply of merchandises in the stores, while the customers only purchase what they need or can afford (ceteris paribus). From the buyers' perspective, computation is easy; the number of buying opportunities can be summarized as in the unconstrained version. From the supermarket perspective computation is less easy however. Every supermarket has to know the strength of competition from surrounding supermarkets in order to estimate the potential amount of consumers. There is currently a well functioning but rarely used model that accounts for the computational needs under conditions such as the potential singly constrained accessibility. The Shen-model (Shen 1998), is estimated in two steps. In the first step the supplies of supermarkets, from the individual's perspective, is computed. This is done similarly to the computational procedures described as for unconstrained models, implying that the sum of supply needs to be accounted for. In equation 2, this is made by using a gravity based distance deterring function; where S represents the location's or individual's summed access to the supermarkets and s represents the single supermarket. In the second step, the potential total access, A, to the surrounding customers is computed as the sum of shares of customer interest. In equation 2b, this is described as C (customers) over S, indicating that the amount of potential customers is known only after competition from other supermarkets is accounted for. Including the distance deterring function means in practice that the model correctly assumes that distant shoppers are less attracted by a supermarket located far away, and when competing supermarkets are included in the model, the attraction is probably decreased further (if alternative supermarkets exist).

(eq.2) $$S_j = \sum_{k=1}^{m} s_k * f(d_{kj}, \beta)$$

(eq.2b) $$A_i = \sum_{J=1}^{n} \frac{C_j * f(d_{ij}, \beta)}{S_j}$$

Potential measures of doubly constrained accessibility

A common competition situation is when both supply and demand is restricted in some way. One may consider such rules of competition as typical in almost any form of market; it may be exemplified by the competition on the labor market and the housing market. In practice this means that individuals can not choose jobs or homes freely, and personnel managers and estate agents can not choose workers or tenants freely either.

There has been no fully functional potential model available for the computation of doubly constrained spatial competition. On most occasions, doubly constrained competition is analyzed using outcome models or potential models that either is not suitable from a model choice perspective (outcome models) or unsuitable from a measurement perspective (non-doubly constrained measures are used in estimation process). The only available potential measure of doubly constrained accessibility has been a specific version of the doubly constrained gravity model, in which the distance decay function is represented by a function expressing a non-place specific friction of distance. If place specific, as it often is, the measure risks becoming an outcome measure rather than a potential measure. The equation is formulated below. As described in equation 3, access is described as the sum of access to jobs, T_{ij}, available in every single location.

(eq.3) $$Access_i = \sum_i T_{ij}$$

(eq.3a) $$T_{ij} = A_i B_j O_i D_j f(d_{ij}, \beta)$$

The “T_{ij}” is calculated using an iterative procedure; where O represents the demand at location *i*, and D represents opportunities at destination *j*. The letters A and B represent the search for alternative opportunities (A) and the search for alternative demand (B). The latter equations 3b and 3c use iterations to determine a “close to actual” value of competition for opportunities.

(eq.3b) $$A_i = 1/\sum_j B_j D_j f(d_{ij}, \beta)$$

(eq.3c) $$B_j = 1/\sum_i A_i O_i f(d_{ij}, \beta)$$

The greater the number of iterations, the “closer to actual” values will be produced. Two problems however make the use of this computation troublesome. First, iterations can not by nature produce “actual values”. This means that, the greater the number of unique places included in the analysis, the greater will the produced bias be. This also means that comparisons between retrieved access-estimates can be problematic, since there is no way of telling whether the difference between access-estimates is due to “actual” differences or due to bias produced as an effect of an insufficient amount of iterations. Secondly, the iteration procedure means that the number of computations increases dramatically; if considering that access should be estimated for each and every individual on a labor market, the relationship between every individual and each job opportunity needs to be estimated through iterations.

Almost needless to say, the doubly constrained gravity model is a poor measure in the description of potential accessibility, at least if individual’s or workplace’s accessibility is to be estimated. Its ability to estimate flows between places of origin and destination, for which the model is intended, is however a completely different issue. Especially, if one takes into account developments of the model that acknowledge individuals’ behavior and choice, see for instance (Fotheringham 1983; Fotheringham, Nakaya, Yano, Openshaw and Ishikawa 2001)

Commonly used measures of potential accessibility

Though named differently in different articles, the "family" of job-housing balance measures is by far the most commonly used measure of potential accessibility, see for instance (Cervero 1989; Giuliano and Small 1993; Cervero 1995; Cervero 1996; Cervero and Wu 1997; Peng 1997; Immergluck 1998; Wang 2000; Åslund, Östh and Zenou 2006). The measure can be constructed differently but shares a common objective namely the creation of a ratio aiming to describe the relationship between supply and demand. The principle of the computation involves the summarization of the, in this example, supply of jobs and the summarization of the, in this example, supply of workers; all from a point of reference common to both summarizations. The principle is visualized in *Figure 3*.

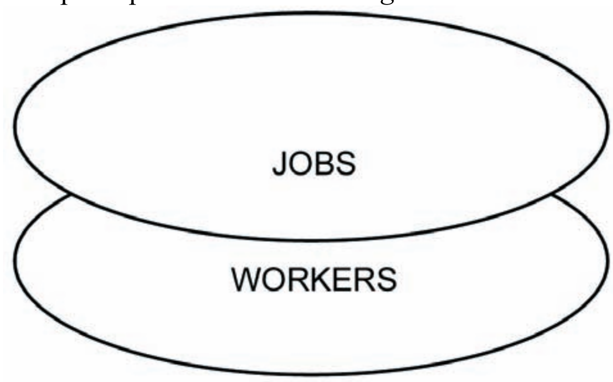

Figure 3. The principle of summarizing supply of workers and supply of jobs in a job-housing balance measure

In the description of the principle of computation, the word supply is used to denote both workers and jobs; this is made intentionally since the values describing the sum of jobs and workers have no natural interrelation as suppliers and demanders apart from the fact that they share location of reference. Hence, a formulation of the job-housing balance measures can be expressed as in equation 4.

$$\text{(eq. 4)} \qquad access_i = \frac{S_1}{S_2}$$

Where the accessibility at location *i* can be expressed as the result from sum of jobs "S_1" over sum of workers "S_2". This crude measure of potential accessibility has the advantage of being easy to compute and easy to explain and it may also easily be developed to involve measures of distance decay, weighting more distant workers or jobs as less important.

However, workers and jobs located in the outer rim of the encircled area probably have a very different set of potential workplaces and potential workers in their catchment-areas, a fact that is not included in the model-building approach. The Shen-model (1998) is modeled to reduce this problem since the model involves that workers' access to jobs is not estimated until the quantity of potential workers surrounding each workplace is known. The principle of summarization is illustrated in *Figure 4*, where the centralmost point and circle denotes the point of reference and the catchment-area. The underlying circles and points refer to workplaces' summarization of potential workers in reference to the workplace-location.

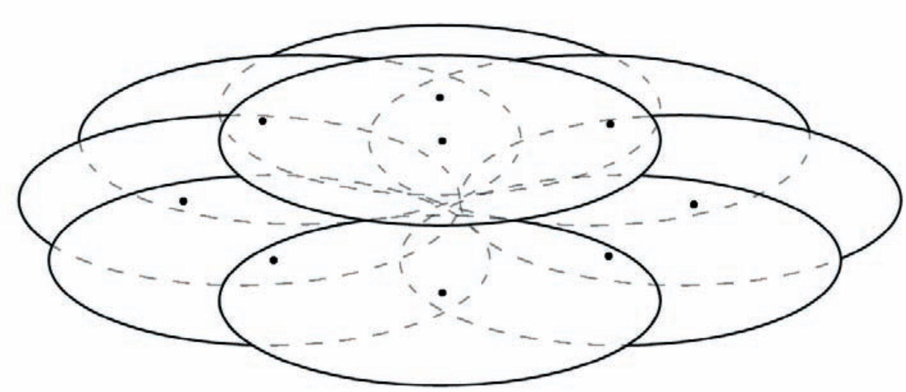

Figure 4. Principle behind the computational procedure for the estimation of accessibility in one location using the Shen-model.

Though the Shen-model estimates the individual's accessibility not only by applying a distance decaying equation but also by weighting the individual's accessibility to work as a product of the amount of workers surrounding each workplace, the measure makes use of the two first links in a chain of possible iterations to improve the results of the equation. As expressed in equation 5, an individual's accessibility is a result of a function describing supply "$f(S_1)$". The supply is a function of demand "$f(D_1)$", which in turn is a function of the supply…

(eq.5)

$$access_i = f(S_1), f(S_1) \leftarrow f(D_1), f(D_1) \leftarrow f(S_2), ..., f(S_{\rightarrow\infty}) \leftarrow f(D_{\rightarrow\infty})$$

Recapitulating the Shen-model visualized in *Figure 4* and using the iterative approach expressed in equation 5 means that "$f(S_1)$" & "$f(D_1)$" are estimated. However, the true "$f(D_1)$"-values (the underlying circles) are not known if we don't know the "$f(S_2)$"-values surrounding each "$f(D_1)$"-value and the true "$f(S_2)$"-values are not known … The iterative approach to estimate the "close to actual" potential accessibility is illustrated in *Figure 5*. In part A the accessibility valid for one location or individual is visualized using a Shen-model approach. The B- and C-parts of the illustration show how an iterative process quickly grows out of control.

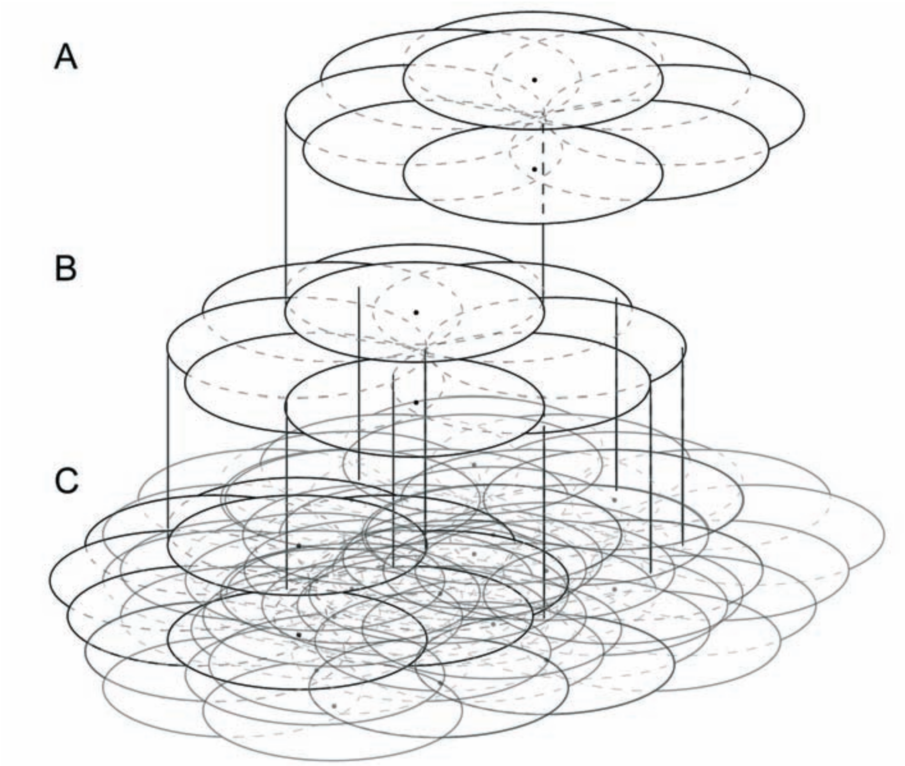

Figure 5. Links in a chain of iterative computations to achieve "close to actual"-values of accessibility.

The use of potential accessibility in this thesis

The last three articles in this thesis make use of different sorts of potential accessibility measures. The first of these three articles (article 3), co-written with Olof Åslund and Yves Zenou, makes use of an outcome-measure of accessibility (commuting distances on individual and neighborhood level) and a potential measure of accessibility (the job-housing balance measure, see equation 4). In article four and five, an entirely new model for the measuring of potential accessibility is introduced. The model, ELMO, is presented in article four and empirically tested and compared to commonly used models of accessibility in article five. In the following sections the ELMO-model is introduced more thoroughly, including modeling assumptions, statistical notation and a description on how to "get going" practically.

Method and theory behind the ELMO-model

In this section the job accessibility model developed and tested in articles four and five is explained. The ELMO-model can be defined as a doubly constrained measure of accessibility, corresponding to the modeling assumptions depicted in the section describing doubly constrained accessibility above. The abbreviation ELMO represents Estimated Labor Market Outcome. The abbreviation reveals that the labor market conditions are the prime focus for the modeling and use of ELMO-models. However, the model aims at mimicking the state of competition on doubly constrained markets, i.e. equilibrium state, which may be factual on the housing market or any other systems of doubly constrained competition. Due to the aims of this thesis and in order to promote a pedagogical description of the model, all examples used to explore the benefits of the models will be presented using the labor market as the scene of competition.

The estimation of accessibility through the use of doubly constrained competition is not an entirely new approach. Formulation and testing of doubly constrained accessibility measures have been successfully accomplished on the Stockholm county during the 70ies and the 80ies, see (Weibull 1976; Weibull 1978; Mattsson and Weibull 1981). These early computations achieve to create a measure that accomplishes to mimic accessibility under conditions of equilibrium. However, greater availability to data and advances in computer technology has made further explorations possible today. Contemporary computation techniques make it possible to estimate a doubly constrained accessibility measure that is beneficiary in many ways. In the following section, the statistical formulation and computational proceedings will be presented. Later on in this section, the benefits of using the ELMO-model are presented and discussed.

The computational proceedings in the ELMO-model are rather complex. In order to assist the reading of the different equations, the equations are grouped from the viewpoint of the equations as being either of supply or demand perspectives. The three groups of computational steps are referred to as: (i) a crude measure of accessibility, (ii) introducing competition for jobs, and (iii) the accessibility to competition adjusted jobs.

ELMO Step 1: A crude measure of accessibility

The first step of computation uses the potential worker's perspective as a starting point. In this step a crude measure of labor market access is defined as the aggregated sum of demand for labor in the surroundings. This aggregated sum of demand is expressed in equation 8, where AD_i represents the aggregated sum of demand accessible from location *i*. However, since the demand for labor is located at different distances from location *i*, certain measures are needed to acknowledge the impact of distance. In equation 8, w_{ij} represents a distance weight, constructed using a distance deterring function which will be used to mimic the probability of traveling over different distances. In addition, a circular catchment area of summarization is defined where a threshold maximum distance can be defined by *R*[3]. The formulation and use of these distance related functions vary, since their use is dependent on the spatial assumptions made in the definition of the model. The distance related functions (topologies) will be discussed further below.

(eq. 8) $$AD_i = \sum D_j w_{ij}, w_{ij} = f(d_{ij}), j \in J = \{j = J \mid r \le d_{ij} \le R\}$$

The total potential amount of demand for labor surrounding location *i* can be related to the local supply of labor S_i (equation 9). The computation of a ratio of *S* over *AD* tells the potential amount of supply of labor available to the demanders at locations *j*. Note that S_i must be constructed in concordance with AD_i, implying that supply decreases just as AD_i decreases when distance increases and that the *R*-value of the catchment area is set at equal distance.

The equation produces a result that informs about the labor suppliers' potential interest in each unit of demand for labor available within the catchment-area.

(eq.9) $$Z_i = \frac{S_i}{AD_i}$$

ELMO step 2: Introducing competition for jobs

In the second step of computations, the focus is redirected from the labor suppliers' perspective to the labor demanders' perspective. In this step the demand for labor is balanced by the surrounding workers' potential labor supply.

In equation 10, AZ_j represents the aggregated sum of Z_i accessible from the labor demanders' location *j*. As in equation 8, the sum is dependent on the modeling assumptions concerning distance, where w_{ji} represents a distance deterring function and where $r \le d_{ji} \le R$ defines the size of the summarization area.

[3] The inner radius *r* is typically set to zero. However, by assigning *r* a value greater than zero, an annulus, rather than a circular catchment area, can be used as the area of summarization.

(eq.10) $$AZ_j = \sum Z_i w_{ji}, w_{ji} = f(d_{ji}), i \in I = \{i = I \mid r \leq d_{ji} \leq R\}$$

The AZ_j value informs about the potential amount of labor supply accessible for every single job demanding labor locally. If the number of workers is greater than the available amount of jobs, the *AZ*-value is typically higher than one, indicating that potential interest of supplying labor is greater than the demand. This condition can be viewed as natural when the number of workers exceeds that of jobs. However, if the job requires rare skills or if the workplace is located unfavorably, the opposite may be factual.

In equation 11 the relation between the local demand (D) for labor and the potential labor supply (AZ) is expressed. The abbreviation DC_j represents demand for labor when competition for jobs is accounted for. Consequently, the DC_j value decreases (increases) in reference to the D_j value as the AZ_j value increases (decreases). From this follows that highly populated areas will have workplace-values with reduced *DC*-values, and the opposite in sparsely populated areas.

(eq.11) $$DC_j = \frac{D_j}{AZ_j}$$

ELMO step 3: Accessibility to competition adjusted jobs

In the third step of computations the competition adjusted jobs are used to compute the labor suppliers' job accessibility. As in the first step (see above), the sum of demand for labor is aggregated to location *i*. The difference from the first step is however that the aggregated sum of demand for labor is weighted to acknowledge the surrounding pool of labor suppliers' competition for the demanded labor. Again, as in equations 8 and 10, the summarization is dependent on the modeling assumptions concerning distance decay and catchment area. The abbreviation ADC_i represents Aggregated DC_i.

(eq.12) $$ADC_i = \sum DC_j w_{ij}, w_{ij} = f(d_{ij}), j \in J = \{j = J \mid r \leq d_{ij} \leq R\}$$

The local estimated sum of employment (*EE*) can be estimated by multiplying ADC_i *with* Z_i. In practice this means that the surrounding competed for jobs (ADC_i) are related to the local labor suppliers' potential interest in the demand for labor available within the catchment-area (Z_i). The procedure is formulated below in equation 13.

(eq.13) $$EE_i = ADC_i * Z_i$$

Depending on the formulation of the model, the acquired estimated *EE*-values can be distributed to the individuals in location *i*, using different equations. In its simplest form, all local labor suppliers share equal interest and skill in each of the surrounding jobs (demand). This situation is formulated in equation 14, where the *EE*-value is divided by the number of labor suppliers in location *i*.

(eq.14) $$Access_n = \frac{EE_i}{n_i}$$

In case the individual's labor supply potential is estimated to be different in comparison to other individuals' supply potential, a more complex individualization procedure is needed. Consider the supply-value (as used in equation 9) in location *i*, S_i, to be the sum of all, locally residing individuals' supply and s_i to represent the individual's supply amount. The individualized access can be derived using equation 15:

(eq. 15) $$access_n = \frac{s_i}{S_i} * EE_i$$

Summary of the equations

Equations 8 to 13 can be combined and formulated as in equation 16 below. To assist the interpretation of the equation, three differently shaded grey areas denote the computational steps presented above. The smallest and darkest of the three areas represents "A crude measure of accessibility", the mid-sized area represents "Introducing competition for jobs" while the greatest and lightest area represents "Accessibility to competition adjusted jobs".

The capital letter Psi, Ψ, replaces all model-specific systems of nominal representation in the calculations. This is practical since different modeling assumptions concerning distance and individual characteristics partly require different calculations.

(eq.16) $$Access_i = \sum_i^{\Psi} \left(\frac{S_i^{\Psi}}{\sum_i^{\Psi} D} * \sum_i^{\Psi} \left(\frac{D_j}{\sum_j^{\Psi} \left(\frac{S_i^{\Psi}}{\sum_i^{\Psi} D} \right)} \right) \right)$$

Assumptions and modeling alternatives in ELMO

The settings in an ELMO-model involves, in its simplest form, all available jobs, all available potential workers and all jobs' and potential workers' locations in a labor market region. The underlying intention of the model is to distribute shares of work to the potential workers as a result of their (workers) success in competing for the available jobs with the other workers. This intention implies that the sum of all individuals' access to jobs must equal the sum of jobs available on the labor market, as formulated in equation 17:

$$\text{(eq.17)} \qquad \sum access = \sum Jobs$$

This computational assumption is important since the estimated access to jobs available to each individual (if modeled to be individual) can be compared to individuals' in other parts of the labor market region or to individual estimates derived using ELMO in other labor market regions. Measures such as the job housing balance ratio model do not produce comparable estimates, since the sum of all estimated accessibility rarely equals the sum of available jobs. This modeling flaw also implies that comparison of individual estimates from various parts of the labor market region or from other estimates of labor market accessibility is not fruitful.

The fact that the sum of accessibility equals the sum of jobs in ELMO-models also means that the effect of various factors can be analyzed using differencing. To exemplify, if all individuals are assumed to have the same distance decay pattern in one analysis, and car-ownership is allowed to influence individual's pattern of distance decay in another analysis; the subtraction of the second analysis' individual estimate from the first analysis' individual estimate exposes the effects of an individual's car-ownership. The differentiating approach hence makes it possible to extract the impact of "sought for" factors. Measurement models where the sum of accessibility does not equal the sum of jobs can not be used to isolate the impact of a factor such as car-ownership. This is factual since any differencing between two sets of analyses may be contested simply because it is impossible to know if estimated results are due to actual effects of the differenced factor or merely a result of biased models.

In all studies of labor market accessibility some considerations concerning time and space must be carried out. These considerations are important since they portray the prerequisites for labor market participation. In many studies all job offerings within the realms of a commutable surface depicts the individual's maximum job availability. Spatial considerations involve the setting of the radius of the realms, while temporal considerations involve the individual's ability to compete for jobs at certain distances. Such considerations may be expressed in different ways but is commonly instrumented through the use of gravity based distance decay functions. In an ELMO-environment, spatial and temporal considerations are essential too. The considerations are split into two groups named topology and individual characteristics, where the topologies express various ways of modeling space and time in ELMO, and where individual characteristics express various ways of analyzing characteristics that influence individuals' ability to participate in the competition for jobs.

Certain elements of the topology-specific modeling have already been introduced in the section describing the ELMO-equations, since equations acknowledging distance decay and/or catchment areas make use of different types of topology. A topology in the ELMO-environment can be perceived of as an empirically or hypothetically based assumption on how individuals are hampered in their mobility by the friction of distance. This also implies that many different types and varieties of topologies can be modeled within an ELMO-framework. However, only two types of topologies are described and used in this thesis, both of which are illustrated in *Figure 6* and discussed in the following text.

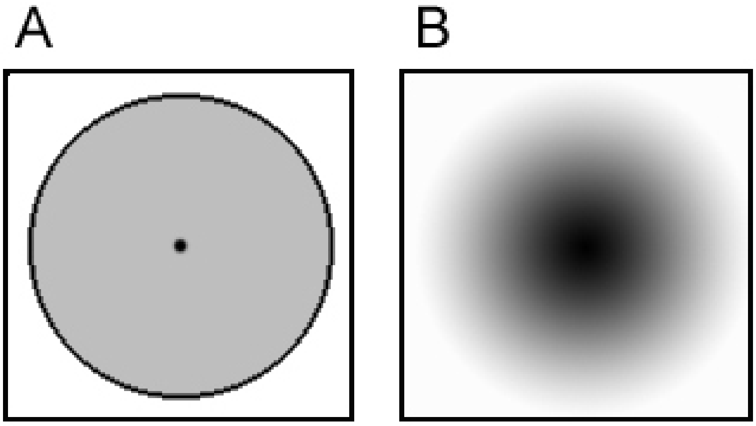

Figure 6. The ELMO topologies: part A represents absolute space topology, AS(), and part B representing relative space topology, RS().

The spatial topologies illustrated in *Figure 6* are: the absolute space topology, AS(), and the relative space topology, RS(). The parentheses used in the topology abbreviations functions as place-holders for information relating to additional choices done in the topology definition, such as catchment-area radius.

The AS()-topology models supply and demand within the bounds of a predetermined geometrical shape. The center of the shape is used to define location *i*, while all locations within the shape are used to define *j*. The RS()-topology is modeled similarly, but discounts the importance of locations *j* in accordance with preferred definitions of distance decay. Common to the

AS() and RS()-topology is that the computations do not make use of predefined destinations, j. Instead the computations make use of the relationships to predefined bounds of space surrounding the locations of origin, i.

The statistical notations of topologies used in this thesis define distance decay and catchment area. Distance decay is formulated using $w_{ij} = f(d_{ij})$, while the catchment area is formulated $r \leq d_{ij} \leq R$. The latter formulation is always needed in the AS()-topology since the demand and supply is defined as being summarized only if the they occur within the predetermined bounds of a circular catchment area, defined by the outer radius "R". The distance decaying weight "W" is included in all other topologies (i.e. all but AS()), but may be modeled differently in different topologies. The gravity based distance decaying functions must be considered as the typical choice, though other formulations are plausible as well. In this thesis, the RS()-topology is decayed using estimations of the probability of commuting over certain thresholds of distances. Since a gravity based distance decay pattern is difficult to produce in a GIS-environment the RS()-topology is produced by summarizing supply and demand using several non-overlapping annuluses. The inner and outer radiuses of the annuluses are defined by $r \leq d_{ij} \leq R$. The distance decay value, W, is produced through estimations of the probability of commuting for distances exceeding that of the outer radius in each of the annuluses. Hence, the RS()-topology makes use of distance decay estimations and catchment areas.

Individual characteristics can also be used within an ELMO-model. This is important since the matching process between demand and supply on the labor market is not fully describable using topologies only. Various factors, representing individual characteristics, can be included to characterize skill-matching, individuals' job search behaviors, discrimination etc. In this thesis, two types of individual characteristics are included, both must however be considered as crude measures of individual characteristics since they only allow for a limited array of characteristics. In article five, an individualized proxy of job search behavior is included to estimate the interest in future job openings. In addition, the matching process between supply and demand for skilled labor is instrumented through labor supply probabilities based on the individual's education. The individual characteristics are used as multipliable factors, increasing or decreasing their individual labor supply potential under different labor market settings.

Practicalities behind ELMO

In this final section describing method and theory behind the ELMO-model, a guideline to the practicalities of actual use of ELMO, using available programs is presented.

Unfortunately, a series of programs is currently needed to complete an ELMO-computation. This is unfortunate for two reasons. First, the greater the number of programs needed to conduct the computation, the greater the assumed reluctance to use the ELMO-model. This since both costs for program purchases and time to learn how to handle the programs increase. Second, the use of different programs and file-formats means that some data is being lost in the translation process in-between programs. Though the translation losses are kept at minute levels, their existence threatens the validity of one of the most important model benefits, the comparison-benefit. A corner-stone in the foundation of all but one of the ELMO-topologies is that the sum of the estimated accessibility is assumed to equal the sum of all demand for labor (the exception being the AS()-topology, see below). This assumption is expressed in equation 18 below, where D denotes demand:

(eq.18) $$\sum access_i = \sum D$$

The exception from this assumption is factual as a result of the modeling approach used in the AS()-topology. The AS()-topology only uses sources of supply and demand that are encircled by the area defined by the radius defining absolute space. This means that sources of demand located outside of the bounds of the encircled area from the perspective of every included location of supply will not be included in the estimation of access, and as a consequence will the sum of access not equal the sum of demand. Due to the modeling design of the AS()-topology and or the unfortunate loss of data in transition between programs, the assumption can be expressed as formulated in equation 19:

(eq.19) $$\sum access_i \approx \sum D$$

The programs used to compute ELMO-models are SPSS and ARC Info, and the file-formats used are SPSS-SAV, Dbase, image-raster (TIFF) and ASCII-text. In the initial stages of computation the material is handled using SPSS. The objective is to create two sets of data-materials describing the geographical whereabouts and characteristics of supply and demand. The databases available during the development of the model have fortunately been consisting of coordinate-data describing the habitual location of individuals (supply) and the location of workplaces (demand). Henceforth workers or potential workers are used to denote supply and workplaces are used to denote demand. The coordinates in these data-materials represent locations at a 100-meters level, making placement very detailed. The first rearrangement of data is the aggregation (summarizing) of workers in accordance with coordinates and the aggregation (summarizing) of workplaces in accordance with coordinate location. If the modeling objective is to estimate an AS()-topology ELMO, the aggregated material is ready for export into Dbase-format. Using other topologies however means that additional information needs to be retrieved. With the RS()-topology as an example, a population-common or individually assessed function describing distance decay needs to be constructed. Using an population-common assessed function means that a function similar to the functions, *f(dij,β)*, used in equations 1-3 is estimated.

In the next step, the Dbase-files are imported into the ARC Info environment. The Dbase-files are used to create point shape-file layers locating demanders and suppliers[4]. However, the following procedures demand that the files are converted into raster-image files. The raster-image files are in all essential constructed to function as image-files, containing three parts of information; the X-location, the Y-location and a place specific value. The conversion procedure is described in row one in Table 1 below.

The next procedure is computed in accordance with equation 8 (see above). Using an AS()-topology, the procedure is fulfilled by summarizing the number of jobs (demand) within a predetermined radius from every predefined location. The predefined locations are in this example determined by the size of pixels in the image-raster file (100*100 meters / see toolbox command syntax). The procedure is described in row two of Table 1.

[4] Using the ”display x and y data”-procedure in ARC Info.

Table 1. *GIS-procedures in the creation of AS()-and RS()-topology ELMO. Notation within "//" in the Toolbox command syntax column refers to authors comments. Italics (7,8) represent obligatory steps in the computation of RS()-topologies only.*

GIS-procedure	Toolbox tool | Path	Toolbox command syntax
1. Conversion to raster	Conversion Tools | To Raster | Feature to Raster	FeatureToRaster_conversion 'shape-file' shape-file column-name "X:\output address" 100 /output cell size (meters)/
2. Summarizing demand "D" creating "AD" (equation 8)	Spatial Analyst Tools | Neighborhood | Focal Statistics	FocalStatistics_sa "X:\input address" "X:\output address" 'Circle, 50,CELL' SUM DATA /five kilometer radius encircling locations *i* defined, using the supply-raster/
3. Creating "Z", Dividing Supply "S" with "AD" (equation 9)	Spatial Analyst Tools | Math | Divide	Divide_sa "X:\input address D" "X:\input address AS" "X:\output address"
4. Summarizing "Z", creating "AZ" (equation 10)	Spatial Analyst Tools | Neighborhood | Focal Statistics	FocalStatistics_sa "X:\input address" "X:\output address" 'Circle, 50,CELL' SUM DATA /five kilometer radius encircling locations *j* defined, using the Z-raster/
5. Creating "DC", Dividing demand "D" with "AZ" (equation 11)	Spatial Analyst Tools | Math | Divide	Divide_sa "X:\input address S" "X:\input address AZ" "X:\output address"
6. Summarizing "DC", creating "ADC" (equation 12)	Spatial Analyst Tools | Neighborhood | Focal Statistics	FocalStatistics_sa "X:\input address" "X:\output address" 'Circle, 50,CELL' SUM DATA /five kilometer radius encircling locations *i* defined, using the SC-raster/
7. Reclassifying null to zero, ADC	*Spatial Analyst Tools | Reclass | Reclassify*	*Reclassify_sa "X:\input address" Value 'NoData 0' "X:\output address" DATA*
8. Summarizing reclassified ADC, creating "SADC"	*Spatial Analyst Tools | Local | Cell Statistics*	*CellStatistics_sa "X:\input" "X:\output" SUM /Several input raster-files "ASC" can be used/*
9. Creating "Access", multiplying "Z" & "ADC" *or "Z" & "SADC"* (equation 13)	Spatial Analyst Tools | Math | Times	Times_sa "X:\input address" "X:\input address" "X:\output address"
10. Conversion of "Access" from raster to ASCII	Conversion Tools | From Raster | Raster to ASCII	RasterToASCII_conversion "X:\input address" "X:\output address"

Equation 9 is performed using the commands described in row three of Table 1. The procedure means that the local labor supply (location *i*) is divided by the local *AD*-value.

In row 4, equation 10 is performed. The result summarizes the local interest in every single job and brings the summed value to places of demand (workplaces).

By dividing the local demand for labor, “D”, with the surrounding supply of interest for jobs, “AZ”, a “DC”-raster is created. The “DC”-raster describes the potential demand for labor in location *j* when the surrounding competition for jobs is acknowledged. The procedure is described in row 5 of Table 1, and is formulated in equation 11.

In row 6 of Table 1, the summarization of “DC” into “ADC” is described. The “ADC”-raster value brings a value describing the potential amount of demand (jobs) available to the suppliers (potential workers) at each location *i*. The procedure is formulated in equation 12. In row 7 and 8 additional, and to row 6 related, computations are expressed. These computations are only needed in an RS()-topology environment. Due to the fact that no single program is yet developed to compute ELMO, the RS()-computations are completed in multiple steps in order to mimic the effects of distance decay on supply and demand. This involves the creation of several “ADC”-raster files which in turn need to be summarized to represent the functionality of the “ADC”-raster in an AS()-topology. The summarization however poses a problem since the merging of several raster-files into one raster-file only produces a value in each cell if all cells in the pile of cells on top of each other, constituted by the layers of raster, contain no missing-data values. To ensure that no raster-file contains null-values, the null-values are replaced by zero in each of the “ADC”-raster-files. This procedure is described in row 7 of Table 1. In row 8 of Table 1, the summarization of the reclassified raster-files is described. It is important to note that the “SADC”-raster-file created as a result of the described procedures in row 7 & 8 is to be used in RS()-topologies as the “ADC”-raster-file is used in a AS()-topology.

In row 9, an “Access”-value is produced at each location *i*. Since the “Z”-value describes the local potential supply of labor, the multiplication of the “Z”-value with the “ADC”-value, describing the sum of demand surrounding location *i*, will produce the local share of demand for jobs available to the local workers. The procedure is formulated in equation 13.

Finally, in row 10 the export of the “Access”-raster is performed. The export-format ASCII is chosen because it is easy to import into a statistical program such as SPSS.

The various computational outputs produced by the ARC Info program are visualized in *Figure 7*. Part A of *Figure 7* illustrates the distribution of workplaces in a Swedish labor market area. The amount of jobs at each location is illustrated using a floating array of grayscale colors, where darker colors represents higher concentrations and vice versa. Parts B and C can both represent the GIS-output in any of equations 8, 10 or 12. The RS()-topology is computed using annuluses of various sizes. These annuluses are created by subtracting GIS-output similar to part C from part B. The subtraction result equals part D. Note however that the spheres and rings visualized in parts B-D must be considered as “trompe l’oeil” since the subtractions occur on pixel-levels only. The spheres and rings visualized are merely a result of the concentration of jobs and individuals in certain areas. The “D” types of rings illustrate true annuluses as produced in the RS()-topology. Through summarization of different-radii annulus, a summed “part D image” of RS() is equivalent to part B or C in the AS()-topology,. Part E illustrates the ADC- or SADC-values (row 8 in table 1). In part F, the *EE*-values are visualized and as in part A, the darker colored areas depict locations with higher values (*EE*-values).

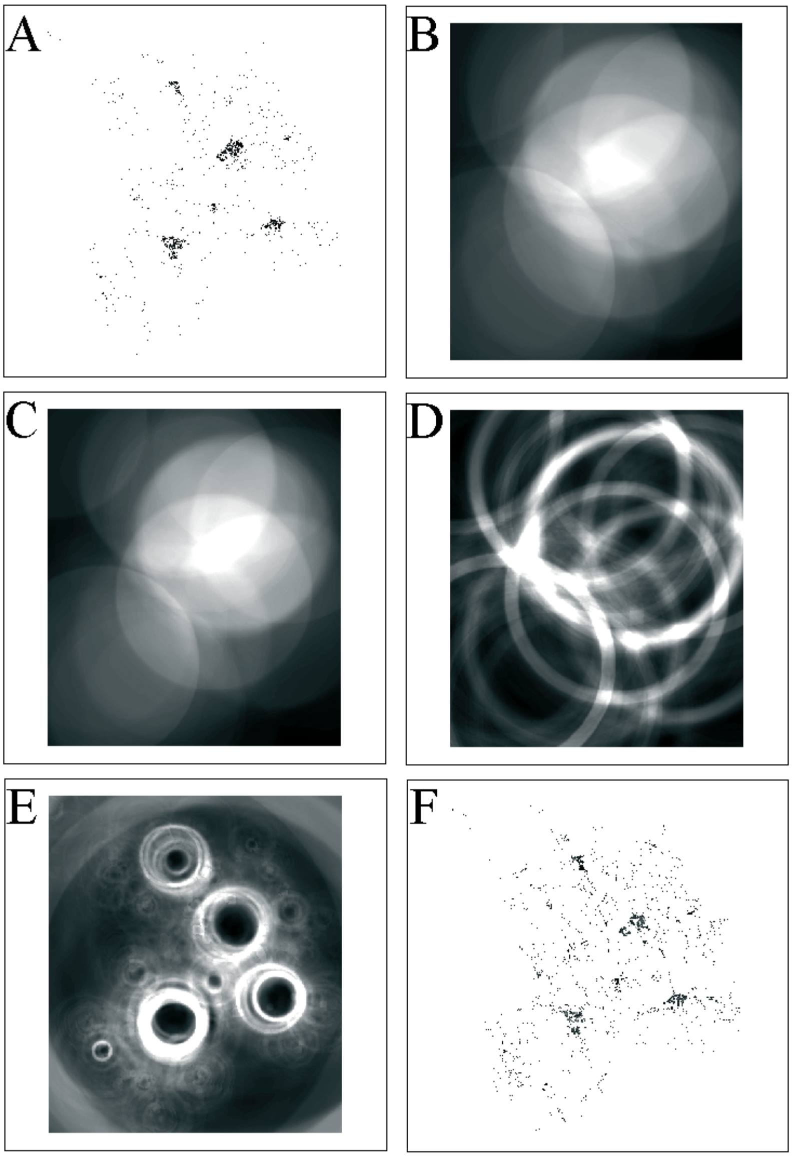

Figure 7. Raster-images derived through computations expressed in equations 8-13.

The process of transferring the access-values between a raster-image via ASCII-text into SPSS is illustrated in *Figure 8*. Step (i) illustrates the arrangement of access-values in a raster-image, where the locations of values are arranged as a matrix, each with a unique place-holder-combination of row- and column-numbers. In step (ii) the raster image-material is exported into ASCII-text. The text material is transposed (R=C, C=R) and values are kept separate by row-breaks and tabs.

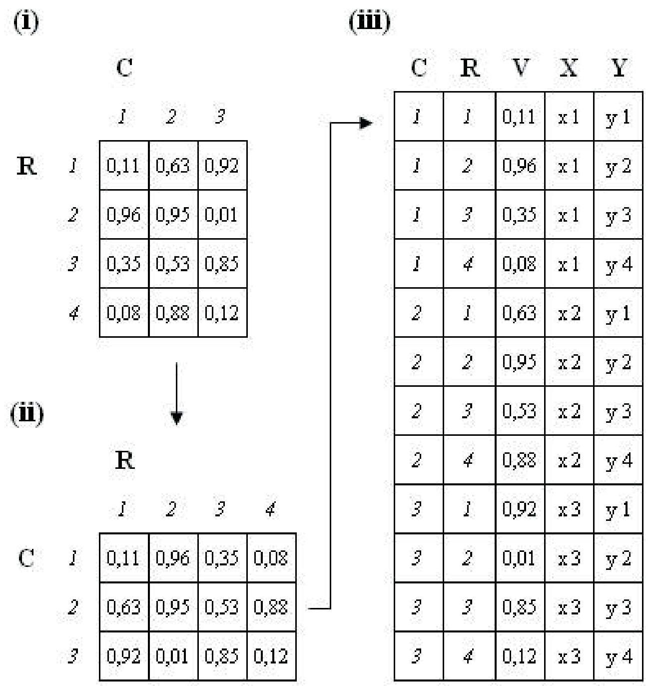

Figure 8. Transfer of data from ARC Info to SPSS. In step (i) the locations defined by the raster image's rows "R" and columns "C" hold values of accessibility. In step (ii) the material is exported and transposed into ASCII-text. In step (iii) the ASCII-material is read into SPSS alongside the ASCII information describing the row "R" and column "C" position for each access-value "V". The row and column-positions are used to construct coordinates (x & y).

In step (iii) the text-file is imported into SPSS. Unaltered, SPSS displays several columns of access-values, but after a "variables to cases"-restructuring of the data-material, the access-values are arranged in a single column, alongside their unique place-holder-combination of row- and column-numbers ("R" & "C" in part (iii)). The place-holders can be used to create coordinates, which in turn can be associated with the coordinates of the suppliers.

The data material used in the computations

All empirical analyses conducted in this thesis are made possible using the PLACE database located at the department of social and economic geography at Uppsala University. From an international standpoint the data materials available for research at Swedish Universities are unique since they include detailed information on individual level for every individual resident in Sweden on an annual basis. The PLACE data base is no exception. It is however crucial to point out that no individual data can be connected to actual residents through names or numbers. It is also important to point out that all research programs are granted admission to the data material only after an ethical board has evaluated the intended research.

In October 2006, the PLACE data base consists of data spanning over the years 1990 until 2004. The data base is composed of two different sets of material. First, individual data describes various elements of demographics, education, employment, income and habitual location. Secondly, workplace data describes various elements of ownership, organization and location. Both sets are combinable since the workplace of an individual is coded in accordance to the coding used to describe the workplace organization.

The data material describing workplaces and individuals is arranged as discrete data entries, representing the individuals' and workplaces' annual status at a fixed measurement period each year. Some individual variables are also represented by other forms of annual records such as the annual sum (income, unemployment days, social benefits etc.) or records from the income taxation (income related).

Summary of the articles

In all, five articles are published in this thesis. The two first articles both study issues related to regions of labor markets, the third article, co-written with Olof Åslund and Yves Zenou, analyses questions of spatial mismatch affecting the labor market situation of refugees in Sweden. Articles four and five introduce and analyze the use of a new measure of potential accessibility, ELMO.

Article one

In the first article in this thesis, the delineation of labor market regions is computed using a homogenous inductive perspective. This means that the labor market is viewed as an entity, possible to delineate. However, the population used in the delineation process is viewed as heterogeneous and consequently split up in groups of belonging. These groups are formed on basis of gender, ethnicity, work-sector, educational level, age and income. Labor market regions are delineated for each of these groups, using the computational procedures described by Statistics Sweden (Carlsson, Johansson, Persson and Tegsjö 1993). The labor market regions delineated correspond to the mobility pattern of various groups, leading to few and large regions for highly mobile groups such as men, high-income individuals and higher educated, while the opposite pattern is factual for groups such as women, low-income individuals and lower educated. Combinations of various groups reinforce the mobility pattern further. An important question in the article is whether the difference in mobility between groups such as men and women increases as the municipal type changes from being the center of the region to being increasingly peripheral. The answer to this question is sought both through visualization of the extent of different labor market regions and through statistical analysis of mean commuting difference between groups in different types of municipals. The answer confirms the hypothesis that differences in commuting between groups increase as the distance from the labor market core municipal increases. Since the enlargement of labor market regions have been a political goal for many years in Sweden, the results points to the importance of analyzing the different propensities for commuting not only as result of being part of a group but as being resident of different municipal types, if the regional enlargement is to prove actual for the entire population.

Article two

In the second article, the delineation of labor market regions is revisited. In this analysis the aim is to identify two sources of population selection bias and propose a possible solution on how to bias-correct the population. The biases are as follows, (i) young individuals residing in their parents homes while working in a labor market region other than the labor market region of residence are probably actually residing in the region of work. (ii) Individuals that commute for very long distances do probably commute on week-basis or do work a considerable amount of days from home.

The two biases are due to the fact that only place of residence is used in the official computational procedures used to delineate labor market regions. Second-hand rental or other forms of short-term tenancies are only rarely registered officially. In all, five different suggestions on how to solve these biases are presented and used to delineate new sets of labor market regions. All variants produce regions that differ from the official delineation of labor market regions. The bias-correction of the population is important in order to construct regions that correspond more closely to the actual pattern of commuting.

Article three

The third article is co-written with Olof Åslund and Yves Zenou. In this article the prime focus is the study of spatial mismatch in Sweden. The individual outcome is measured in terms of employment and income, and spatial matching is studied as a result of the proximity to jobs. The proximity to jobs measure is composed of a job housing balance measure, and a mean-commuting distance value as a proxy for the neighborhood's location relative the labor market. Since commuting distance is used to describe job accessibility, a Swedish refugee dispersal policy is used to minimize the commuting distance-effects created as a result of endogenous choice of residential location. In the analysis the allotted habitual location of refugees arriving to Sweden in 1990-1991 is used as exogenously given. The results from the analyses show that refugees placed in locations with poor job access in 1990-1991, had an adversely affected labor market outcome in 1999. The results from this study point to the importance of the whereabouts of residential location for the outcome of future employment possibilities, and due to the results it is crucial that future decisions on refugee placement policies widen the perspective from a predominantly regional political one to a perspective including the individual's labor market outcome.

Article four

In article four an entirely new method for the measurement of potential accessibility is introduced. The ELMO-model (Estimated Labor Market Outcome) is a time-geographically based methodology for the study of doubly constrained potential accessibility (se above) and as such it is suitable for the analysis of competition under conditions where both supply and demand can be constrained (doubly constrained). In this theoretical and introductory article the ELMO-model is tested against the commonly used job-housing balance ratio measure and the Shen-model, see (Cervero 1989; Shen 1998) for details. Two tests are conducted using a hypothetical population on a likewise hypothetical island of 10*10 geographical units. The first test reveals that the models estimate individuals' access to jobs in ways that are strikingly different. In the second test the effects of a job-shock (withdrawal of jobs from a geographical unit) affects the population on the island. The results of the analysis of the outcome of the two tests reveal that the job-housing balance ratio measures perform poorly in both tests, both failing to encompass all jobs offered on the island and failing to spread the effects of the job-shock to others than the individuals residing in absolute proximity to the shocked unit. The Shen-model succeeds to encompass all jobs on the island but fails to spread the effects of the job-shock to adjacent units. The ELMO-model succeeds in both tests, by encompassing all jobs on the island and spreading the effects of the job-shock to many location-units on the island.

Article five

In the final article the ELMO-model is empirically tested against job-housing balance ratio measures in a Swedish labor market region. The intentions behind the tests are not to test the validity of hypotheses such as the spatial mismatch hypothesis but rather to test the validity of the tools used to estimate accessibility, commonly used in these hypotheses. The prime focus is consequently to critically evaluate the outcome of the tested measures, and to recommend accessibility measures that can prove to be valid in tests of spatially oriented hypotheses of supply and demand. The article consists of a wide array of smaller tests group-able into three larger groups. In the first group of tests model-estimates are tested on the grounds of their statistical and spatial representation. The results indicate that the job-housing balance ratio measures fail to encompass all jobs on the labor market, and produce estimates that deviate strongly both statistically and spatially. The so-called plain ELMO-models also perform unsatisfyingly while the structured ELMO-models excel. In the second group of tests, the models are tested against various commonly used factors, such as income, gender, employment etc. The results support the future use of structured ELMO-models. Finally, the models are compared on basis of their ability to derive the effects of change. The principle behind this test is to subtract the individual outcome factual under condition A with the individual outcome factual under condition B, deriving the individual effect of the use of condition A. Due to the measurement related biases presented in test-group one, no derivation of the effects of change is possible using job-housing balance ratio measures. The ELMO-models are however usable for this purpose.

The result of the article indicates that spatially related analyses of the relationship between supply and demand, such as the spatial mismatch hypothesis, would benefit from the use of ELMO-models.

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