

The Spatial Mismatch Hypothesis: Critique of Research and Proposed Methods

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ABSTRACT

After John Kain (1968) advanced the spatial mismatch hypothesis (SMH), a lot of empirical studies have been done with aggregate level and with individual level data. Although the majority of the findings support the SMH, inconsistencies do exist. The findings, regardless of whether they support the SMH, come from conceptually incorrect models in which the endogeneity of residence is not taken into account or which use biased samples. Thus, the findings are either unreliable or subject to strict constraints in generalization. In this paper, the authors propose three generalizable structural equation models to test the SMH with aggregate level data.

Key words: spatial mismatch hypothesis, endogeneity, structural equation modeling

1. INTRODUCTION

In the past thirty-five years, the Spatial Mismatch Hypothesis (SMH) has been tested in many empirical studies. These empirical studies have tested different dimensions of the SMH (Ihlandfeldt and Sjoquist, 1998). The papers on the relationship between employment and job accessibility outnumber those on other dimensions. The findings, especially in the 1990s, are more consistent and support the SMH.

However, two important research problems have not been solved yet. The first one is the endogeneity issue. In the spatial mismatch context, the endogeneity of residence and the endogeneity of auto ownership are not taken into account in the multiple regression models and logistic regression models. The endogeneity bias lowers the reliability of the estimates. The second problem is sampling bias, which makes the models not generalizable.

This paper is motivated by the need for a generalizable method that can overcome these two problems. Rather than using conventional multiple regression and logistic regression, we propose three new structural equation models.

2. LITERATURE REVIEW

The Spatial Mismatch Hypothesis is the idea that, as jobs, especially low-skilled jobs, decentralize from the urban center, many urban poor blacks are left without easy access to employment (Holzer, 1991). The farther jobs move from impoverished neighborhoods, the more difficult it becomes for the blacks to find work. Kain (1968) first discussed this in an empirical study in Chicago and Detroit. He found that the employment of inner-city blacks was negatively associated with the distance between their residence and employment opportunities. Since Kain's paper, a lot of empirical studies have been done to test the impacts of isolation of poor neighborhoods from low wage, low skill jobs. A key question for Kain is whether blacks are more subject to the impacts of job decentralization than the rest of the population. Although Kain does not use the term, his findings are the basis for what is termed the Spatial Mismatch Hypothesis by other researchers (Ellwood, 1986; Holzer, 1991; Kasarda and Ting, 1996; Arnott, 1998; Ihlandfeldt and Sjoquist, 1998; Raphael, 1998; Ong and Miller, 2003). Kain used the term, but did not explicitly define it in his later review (1992). The following was thought by Arnott (1998) to be Kain's (1992) definition of the spatial mismatch hypothesis: "Serious limitations on black residential choice, combined with the steady dispersal of jobs from central cities, are responsible for the low rates of employment and low earnings of Afro-American workers" (Kain, 1992, p.371).

Ihlandfeldt and Sjoquist (1998, p.851) summarize the spatial mismatch hypothesis: "A simple statement of the SMH is that there are fewer jobs per worker in or near black areas than white areas. As a result, blacks may have greater difficulty in finding work, may be paid less, or may have to make a longer commute in comparison with whites with similar job credentials. Underlying the SMH are the following premises: (1) The demand for labor has shifted away from neighborhoods where blacks are concentrated in favor of high-growth, mostly suburban areas; (2) racial discrimination in housing and mortgage markets has prevented blacks from moving to where job growth exists; and (3) customer discrimination against blacks, poor information about distant job openings, limited public transportation linkages between black neighborhoods and areas of job growth, and possibly other factors have restricted the ability of blacks to commute to and work in job-rich areas."

This hypothesis has been tested by many empirical studies (Mooney, 1969; Master, 1974; Ellwood, 1986; Hughes and Madden, 1991; Ihlanfeldt and Sjoquist, 1989, 1990a, 1990b, 1991; Cooke, 1993, 1996, 1997; Holzer et al., 1994; Yinger, 1995; Taylor and Ong, 1995; Holloway, 1996; Kasarda and Ting, 1996; McLafferty et al., 1992; McLafferty and Preston, 1996; Wyly, 1996; Thompson, 1997; Immergluck, 1998; Raphael, 1998; Ong and Miller, 2003). The empirical studies have tested different dimensions of the SMH (Ihlanfeldt and Sjoquist, 1998). The papers on the relationship between employment and job accessibility outnumber those on other dimensions. This paper will discuss the empirical studies along this dimension.

As we can see from Table 1, the majority of the empirical studies are done with multiple regression (ordinary least squares) and logistic regression. Some results are the same as the SMH expects, and some not. Inconsistencies do exist among the empirical studies. In their literature review, Kain (1992) and Ihlanfeldt and Sjoquist (1998) argue that the main reasons why some research does not support the spatial mismatch hypothesis are improper measures of job accessibility (for example, Ellwood, 1986) and failure to take into account the endogeneity of residence, especially the latter (for example, Wheeler, 1993; Pastor and Adams, 1996; Cooke, 1997).

In spatial mismatch context, some people may voluntarily choose to live in the places that are close to their jobs. Their choice of residence may be affected by the locations of their jobs and employment status. If so, their employment status and job accessibility is not orthogonal because the job accessibility is a function of residential location. This is generally called endogeneity of residence. In other words, the residential location is not exogenous to employment, and the causality is not unidirectional. The interactions between employment and job accessibility may be direct or indirect through other variables. In any analysis of the relationship between employment and job accessibility, ignorance of the endogeneity will result in endogeneity bias, which may vary in magnitude across cities and lower the reliability of estimates, regardless of whether the results support the SMH or not.

As suggested by Ihlanfeldt and Sjoquist (1990b), two approaches can be adopted to improve the reliability of the estimates. The first approach is to sample the people whose residence is strictly exogenous to their employment. Youth who live with their parents are thought to be the sample that meets this condition. This approach was very popular in the 1990s. Studies with this approach provide supportive results to the SMH. However, as they argue in their later literature review (Ihlanfeldt and Sjoquist, 1998), this approach has at least three shortcomings. First, the exogeneity of residential location holds only if the parents' residential location choice is exogenous, which is hard to prove. Second, youth who do not live with their parents are excluded from the sampling, which results in biased samples. The unemployment ratio may be overestimated due to the fact that youth with jobs are more likely to choose not to live with their parents. Third, the findings cannot be generalized to all youth and adults.

The second approach is to design a simultaneous equation system that can include both employment and job accessibility as endogenous variables. Obviously, the multiple regression (ordinary least squares) models and logistic regression models are not the equation system. The existence of endogeneity of residence violates the premise of multiple regression analysis. It will unavoidably result in biased estimates (Kline, 1998; Finkel, 1995). Whether the coefficient of job accessibility is significant depends on the magnitude of the direct reciprocal impacts or indirect impacts of employment or both on job accessibility. Conceptually, regardless of whether the coefficient of job accessibility is statistically significant, the estimates are not reliable due to the bias.

Unfortunately, to our best knowledge, except Kasada and Ting (1996), Wyly (1996) and Ong and Miller (2003), all past empirical studies are subject to either sampling bias or incorrect

choice of models. Therefore, the findings in these studies, no matter whether they support the SMH or not, are questionable. So are the estimates in logistic regression models.

Ong and Miller (2003) use a two stage regression model to study the impacts of job accessibility, and transportation access on employment ratio and unemployment rate in Los Angeles. They solve the endogeneity of car ownership by introducing an instrumental variable for predicting car demand, which is designated as a linear function of car insurance index, population density and bus availability, in the first stage. In the second stage regression, job accessibility is treated as orthogonal to the employment ratio. Therefore, their estimates are subject to the same problems as the multiple regression.

Kasarda and Ting (1996) and Wyly (1996) use a totally different method to explore the relations between variables in the spatial mismatch context. Using full-information maximum-likelihood (FIML)-based structural equations modeling, Kasarda and Ting (1996) study the feedback relations between unemployment rates, welfare enrollment rates, and poverty rates across cities. In their conceptual model, skill mismatch, which is measured by the percent of city jobs held by persons with more than a high school education versus percent of out-of-school adult residents with less than a high school education, and spatial mismatch, which is measured by the average number of minutes for the one-way work commute of city residents, do not affect each other. Neither of them increases the joblessness for males or females. The percent of persons who have a high school education or less is assumed to increase skill mismatch and spatial mismatch. The percent of low-skilled industry jobs in 1980 is assumed to decrease skill mismatch and spatial mismatch. The percent loss of low-skilled industry jobs between 1980 and 1990 is assumed to increase skill mismatch and spatial mismatch. A higher residential segregation index in 1990 is assumed to increase spatial mismatch. Higher joblessness is assumed to increase the poverty rate. A higher poverty rate is assumed to increase the welfare rate. The welfare rate may increase or reduce the unemployment rate. Their data are aggregated at the city level. They find that the percentage of females on welfare has no significant impact on female unemployment; the male welfare rate increases the male unemployment rate; the percentage of persons who have a high school education or less has no significant impact on spatial mismatch; the percent loss of low-skilled industry jobs between 1980 and 1990 has no impact on spatial mismatch; and all other impacts are significant and the directions are the same as expected. It is noted that the percentage of persons who have a high school education or less and the percent loss of low-skilled industry jobs between 1980 and 1990 indirectly increase percent male joblessness and female percent joblessness by increasing skill mismatch rather than spatial mismatch.

Wyly (1996) used structural equation modeling to explore the impacts of occupational segmentation, industry segmentation, worked hours, and hourly wages on commute distance for black males, black females, white males and white females. He did not find any statistically significant differences between blacks and whites in commute distance, and found that commute distance is determined by hourly wages and worked hours.

The foci of Kasarda and Ting (1996) and Wyly (1996) are not the relationship between employment and job accessibility. It is not surprising that their results do not provide strong support to the SMH. However, their modeling method sheds light on how to integrate employment and job accessibility into a system as two endogenous variables.

Structural equation modeling is an *a priori* simultaneous equation system. This system consists of endogenous and exogenous variables. The exogenous variables will impose their impacts on endogenous variables, but will not be affected by endogenous variables. The endogenous variables are connected each other through unidirectional or bi-directional causality. Since this system can solve the endogeneity problem, it is not subject to sampling constraints as

found in the past empirical studies. Therefore, structural equation modeling is a conceptually superior approach to test the SMH. In this paper, we will introduce a model series which have different foci and elucidate different issues of the SMH.

Table 1 Summary of literature on spatial mismatch

Paper	Data and unit of analysis	Sample	Research Method	Dependent Variable	Primary independent variable	Findings
Kain, 1968	Chicago, 1956 and Detroit, 1952 AREA Traffic Study Survey; zone level	Pooled data for blacks	Multiple regression	Share of black workers in each zone	Distance to major ghetto; distance to nearest ghetto; Black share of workers residing in a zone	Share of black workers in each zone positively associates with racial composition, and negatively associates with distances between work and residence.
Mooney, 1969	Census 1960; SMSA level	The blacks in the poorest tract; 25 SMASs	Multiple regression	Employment-population ratio	Ratio of the jobs of a sector in central city to the jobs of that sector in the SMSA	Employment-population ratio increases with the job shares in central cities of all occupations.
Greytak, 1974	Journey-to-work survey data; city level	1965 interviews in the cities across U.S.	Multiple regression	Work trips	Time cost of the journey to work*; work trip origination dummy, 1 if from central; race dummy; mode dummy	Nonwhite have higher time cost; number of work trips negatively associate with work trip origination from central city; time cost of nonwhite work trips increase with city size, while goes down for Whites.
Masters, 1974	Census 1960; SMSA level	Large SMSAs	Multiple regression	Ratio of non-white to white median income	Residential segregation indices	None of the indices have significant impacts on the ratio of non-white to white median income.
Ellwood, 1986	Census 1970; tract level	Black youth and white youth out of school; Chicago;	Multiple regression	Employment rate	Five measures of job accessibilities, See Table 2	All job accessibility measures have no significant impacts on the employment rate of White and Black youth.

Table 1 Summary of literature on spatial mismatch (Countined)

Farley, 1987	Census 1980 and Census 1977 for four industries; SMSA level	Black and Hispanic males over 16	Multiple regression	Unemployment rate	Job shares for four industries; Black share of population; education inequality	Black male unemployment rate tends to be high relative to that of White males where the metropolitan area has high percentage of blacks, decentralized jobs, centralized black population and a high level of racial inequality in education attainment.
Ihlanfeldt and Sjoquist, 1990a	1980 Public Use Microdata Samples; individual level	Philadelphia SMSA	Multiple regression; logistic regression	Partial derivatives of Employment probability ($\ln(P_{ji}/P_{4i})$)	Mean travel time of youth; mean travel time of all low wage workers	Nearness of jobs increases the likelihood of black and white youth. Nearness of jobs is attributed to the racial differentials.
Ihlanfeldt and Sjoquist, 1990b	1980 Public Use Microdata Samples; individual level	Chicago SMSAs, youth who live with parents	Multiple regression	Partial derivatives of Employment probability ($\ln(P_{ji}/P_{4i})$)	Family income categories; residential location dummies	Residential location has significant impacts on White youth and Black youth. Racial differential is attributed to residential segregation.
Ihlanfeldt and Sjoquist, 1991	1980 Public Use Microdata Samples; SMSA level	23 SMASs	Logistic regression	Employment probability	Commute time; income categories	Job accessibility increases the likelihood of employment for White youth and Black youth.
Taylor and Ong, 1995	American Housing Survey, 1977/1978-1985; zone level	10 metropolitan areas	Multiple regression	Commute distance; commute time	Age; travel mode; education; race; residential mixed area; minority area	The travel pattern of white and minority workers diverges over time. The commute distance of the non-moving workers in minority areas decreases. The findings do not support SMH.
McLafferty and Preston, 1996	1980 and 1990 Public Use Microdata Samples; individual level	New York CMSA; persons with a job	Multiple regression	Mean commute time	Race; gender; travel mode; mean weekly income	Black men and women in central city have longer commute than Whit men and women. Spatial mismatch does not exist in suburban areas, and does not exist in Latino.

Table 1 Summary of literature on spatial mismatch (Continued)

Holloway, 1996	1980 and 1990 Public Use Microdate Samples; MSA level	50 largest metropolitan areas; teenagers	Logistic regression	Employment probability	1980 average commute time of low-wage workers; 1990 average commute time of low-wage workers; index of youth labor demand;	The impacts of job accessibility decline between 1980 and 1990. The black teenagers living in job-accessible areas have no advantages in 1990 to those living job-inaccessible areas.
Wyly, 1996	1980 and 1990 Public Use Microdate Samples	Minneapolis and St. Paul; employed workers	Structural equation modeling	Endogenous variable: hourly wages; working hours; commute distance	Exogenous variable: industry segmentation; occupation segmentation	No evidence of increasing commute distances among blacks is found.
Kasarda and Ting, 1996	1980 and 1990 Public Use Microdate Samples; Housing Summary Tape File 3A; the Urban Underclass Database; city level	67 large cities	Structural equation modeling	Endogenous variable: % female jobless; % female in poverty; % female on welfare; % male jobless; % male in poverty; % male on welfare; skill mismatch; spatial mismatch	Exogenous variable: 1990 % high school or less; 1980 % low-skilled industry jobs; 1980-1990 % loss of low-skilled industry jobs; 1990 residential segmentation index	Skill mismatch and spatial mismatch are positively associated to percent jobless for male and female. Residential segmentation index is positively associated with spatial mismatch. The percent loss of low-skilled industry jobs have no effects on spatial mismatch. The percent low-skilled industry jobs decreases spatial mismatch.
Raphael, 1998	Census tract 1980 and 1990; tract level	Bay Area, California; youth	Multiple regression	Employment rate	Job growth in different industries; job levels	Job growth other than job levels has significant impacts on employment rate. Black youth have higher access to job levels and lower access to job growth than white youth.
Ong and Miller, 2003	Census tract 2000; tract level	Los Angeles	Two-stage regression	Employment rate	Job accessibility; households without cars	Job accessibility has no impacts on employment rate for male and female.

3. CONCEPTUAL MODELS OF THE SPATIAL MISMATCH HYPOTHESIS

When we test the spatial mismatch hypothesis, we are really testing how the employment ratio is affected by job accessibility and other variables and how the employment ratio affects job accessibility and other variables in turn. Therefore, it is of great importance to build a conceptual model before starting to test the relationships among the variables since the conceptual model will determine what structure should be used. In the literature, the traditional multiple regression method preferred by researchers assumes the employment ratio is affected only by exogenous variables. The impacts of endogenous variables on the employment ratio are either assumed to be exogenous or excluded from the models, which is inconsistent with theory. Therefore, it is not surprising that there are so many inconsistencies in the empirical studies.

3.1. Cross-Sectional Structural Equation Model of the Spatial Mismatch Hypothesis

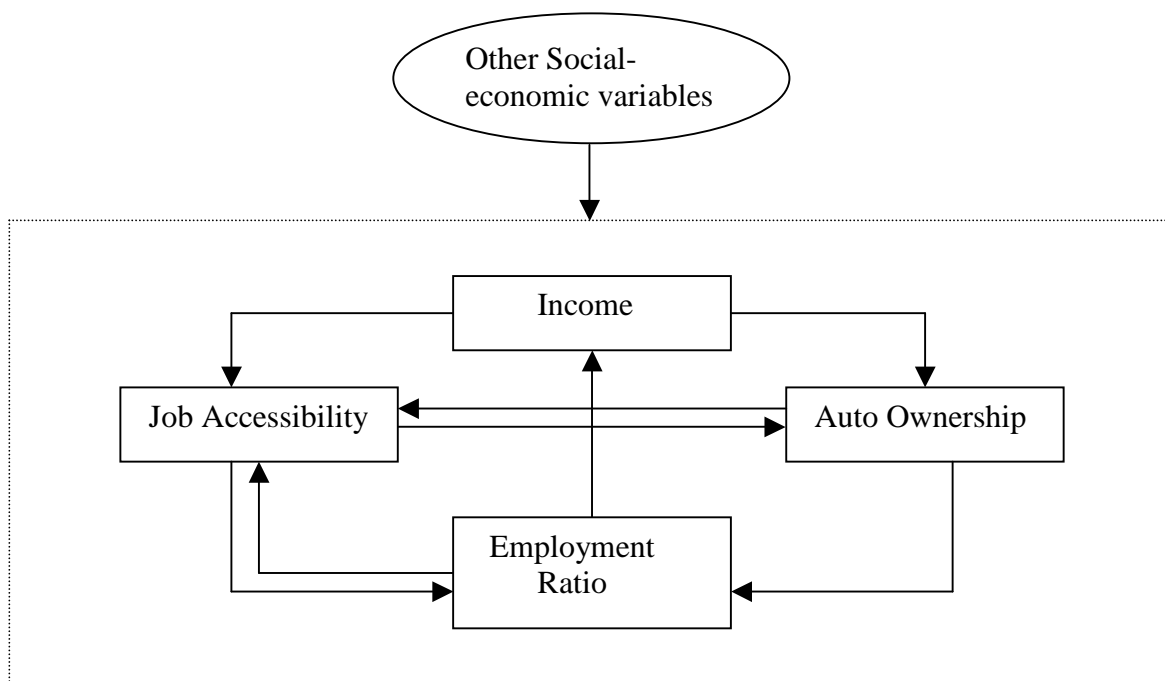


Figure 1 Cross-sectional conceptual model of the SMH

Figure 1 illustrates a conceptual model of how the endogenous variables (within the dotted line rectangle) and exogenous variables are affected by each other. The relations are built based on urban economic theories and results of empirical studies. The arrow represents the direction of the influence. Four endogenous variables are included in the model: employment ratio, auto ownership, income, and job accessibility. They influence each other unidirectionally or bi-directionally. Socio-economic variables impose effects on the endogenous variables, but are not affected by them. Due to the existence of reciprocal interactions and loops, this model is a nonrecursive model.

3.1.1 Direct Impacts of Endogenous Variables

Impacts of Job Accessibility. Job accessibility is a core variable in spatial mismatch hypothesis testing. According to the spatial mismatch hypothesis, it is expected that job accessibility will have significant, positive impacts on employment ratios of blacks and whites. The employment ratio of blacks is expected to be more sensitive to job accessibility than that of whites because blacks are subject to housing segregation and employers' possible discrimination. Therefore, the magnitude of impacts of job accessibility on blacks and whites should be different and the differential of impacts should reflect the difference between blacks and whites in accessing jobs. Job accessibility may have no effect on the employment ratio of whites because whites are unlikely to be subject to housing segregation and may choose to live far from jobs. In the literature, job accessibility is defined differently and result in different outcomes (Ellwood, 1986, Kockelman, 1997, Immergluck, 1998, Raphael, 1998, Ong and Miller, 2003). We think Raphael's (1998) method is the best.

Job accessibility is assumed to negatively affect auto ownership. First, the people or households without private autos may intentionally choose to live in neighborhoods with high job accessibility by non-auto modes, given there is no racial discrimination in the housing market and people can choose to live where they want. Second, autos have no substantial marginal benefits for people living in neighborhoods with high job accessibility by non-auto modes. From the perspective of economics, the high fixed and variable costs make autos a luxury good for people with low incomes and lower their desires to own autos. Kockelman (1997) finds that job accessibility, which is measured by total jobs within 30 minutes' auto travel, is negatively associated with auto ownership.

Impacts of Auto Ownership. It has been found that auto ownership increases employment. Raphael and Rice (2002) find that there is a large difference between the employment rates of youth with and without private autos. Ong and Blumenberg (1998) and Cervero et al. (2000) find that owning a car significantly increases the probability of welfare participants being employed.

Auto ownership is expected to have a negative impact on job accessibility. Urban economic theories predict that people with high auto ownership will more likely live far from jobs to gain higher residential amenities (Holzer, 1991). The empirical evidence supports the theories (Schimek, 1996).

Impacts of Employment Ratio. The outcomes of the labor market can be represented by several different variables. In the proposed study, we will use employment ratio, which is the ratio of total employed population over total population aged 16 to 64 in a census tract. Rather than a dependent variable as in multiple regression modeling, in structural equation modeling, employment ratio will be set as an endogenous variable that imposes impacts on other endogenous variables, and in turn is affected by other endogenous variables. It is common sense that labor income is a consequence of employment and is the main source of income for the majority of households. Employment ratio has positive and direct impacts on income, but will not be determined by income. The impact is unidirectional.

The direct impact of employment on job accessibility is designed to capture the impact of employment on the voluntary residence self-selection which is opposite to the residence selection on the condition of income. This impact is assumed to exist (Ihlanfeldt and Sjoquist, 1989, 1992; Kain, 1992), but has not been empirically tested.

Impacts of Income. There is little doubt that income is the most important determinant in auto ownership (Kockelman, 1997; Golob and Wissen, 1989; Dargay, 2001). The owner has

to pay the fixed cost (purchase, registration, insurance) and variable costs for gasoline and maintenance fees. These expenses result in low auto ownership among the poor (Ong and Blumenberg, 1998; Dargay, 2001).

Income is assumed to have negative impacts on job accessibility. According to urban economics, people with higher incomes have flatter bid-rent curves and are more likely to make tradeoffs between housing amenities and commute costs. People with lower incomes have steeper bid-rent curves, and are more likely live closer to jobs, and usually have higher accessibility in all modes. The pre-examination of census data in our Sacramento County study region shows that people with higher incomes live farther from jobs.

3.1.2 Indirect Impacts of Endogenous Variables

The endogenous variables affect each other not only directly, but also indirectly through feedback loops. The indirect impacts are very important in the spatial mismatch context, because they are a part of the endogeneity. This part may be very large and cannot be ignored in spatial mismatch modeling and policy analysis. Through structural equation modeling, the magnitude of indirect impacts can be quantified and separated from the direct impacts. In this model, we assume the following indirect impacts exist:

- Employment ratio → Income → Auto ownership
- Employment ratio → Income → Auto ownership → Job accessibility
- Employment ratio → Income → Job accessibility
- Employment ratio → Income → Job accessibility → Auto ownership
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- Auto ownership → Employment ratio → Income → Job accessibility

Among the indirect impacts, the indirect impacts of employment ratio on job accessibility are of special interest. Combined with the direct impacts, they will quantitatively address the endogeneity.

3.1.3 Impacts of Exogenous Variables

Socio-economic variables are widely used in travel behavior and spatial mismatch modeling (Ihlanfeldt and Sjoquist, 1990a, 1991; McLafferty et al., 1992; Schimek, 1996; Kockelman, 1997; Ong and Blumenberg, 1998; Preston et al., 1998; Rachael, 1998; Cervero et al., 2000; Ong and Miller, 2003). They affect endogenous variables, but are not affected by endogenous variables. Each endogenous variable may be affected by different exogenous variables. An exogenous variable may affect different endogenous variables in different magnitudes. For example, household characteristics affect income, auto ownership, and residential location choice.

Besides the considerations based on the impacts of exogenous variables, including exogenous variables in the structural equation models is indispensable to meet the conditions for model identification. However, the focus of this study is the relationships among the endogenous variables. We do not intend to include all possible exogenous variables in the model. The selected variables and their definitions are listed in Table 3.

Impacts of Competing Labor Supply. It seems to be intuitive that competing labor will impose a direct impact on employment ratio on the job demand side. Job accessibility gives out the job opportunities on the job supply side. Theoretically, all labor within the region, even outside the region, may compete for the jobs in a specific census tract in Sacramento County, which is the test bed of this study. However, the competition for jobs will become weaker with the increase of travel distance. In this case, we only take into account the competing labor within the research boundary. Thus, each census tract will have a measured value of competing labor supply. The calculation method will be the same as Raphael's (1998). From the calculation of competing labor supply, we can see that this variable will not affect income, auto ownership, or job accessibility.

Impacts of Education. Education represents job skills, and thus affects employment ratio and income (Ilanfeldt and Sjoquist, 1989, 1990a, 1990b; Blumenberg and Shiki, 2003). In this study, this variable is measured by the percentage of persons aged 16-64 and have a college degree. It is expected to have positive impacts on employment ratio and income. Some empirical studies (Bhat and Koppelman, 1993; Meurs, 1993; Raphael and Rice, 2002) include an education variable in car ownership logit and regression models. We argue that education associates with car ownership through the impacts of income, rather than imposing direct impacts. This variable has no direct impacts on car ownership. There are no empirical studies on the causality between education and job accessibility.

Impacts of Household Size. Empirical studies (Meurs, 1993; Kockelman, 1996) have found that household size has significant impacts on auto ownership. It is reasonable to assume that the bigger households will more likely have autos. Household size is unlikely to affect job accessibility because job accessibility is not a function of household size. Household size is unlikely to directly affect employment as well. Since income is measured by median household income, household size will not affect income in this case.

Impacts of Car Insurance Premium. Ong and Miller (2003) find that car insurance premiums have significant impacts on auto ownership in Los Angeles. It might also be true in Sacramento County, although Sacramento has a smaller geographic size and thus the variation of auto insurance premiums may be smaller.

Impacts of Transit Availability. Transit is a substitute mode for private autos. The central city of Sacramento has better transit services than the suburban areas. Ong and Miller (2003) find that transit availability has significant impacts on auto ownership in Los Angeles. It is reasonable to include this variable in the SEM. No empirical evidence has shown that transit availability has direct impacts on employment, income, or job accessibility.

Impacts of Rental Housing Density. Rental housing density is an indicator of neighborhood characteristics and affects people's residential choices, and thus affects job accessibility. In census data, the rental housing units include all housing types for renting. By comparing the census data with Sacramento County parcel data, we have found that the main components of rental housing units are apartments and townhouses and rental housing is largely excluded from suburban areas.

Rental housing density may correlate with employment ratio, income, and auto ownership because the neighborhoods with high rental housing density may attract the low

income households. However, it should not be thought as the determinant of employment ratio, income, or auto ownership.

Impacts of Average Housing Age. Housing age is one of the determinants of housing price or rents, and thus one of determinants that affect people’s residential location choices. The poor and minorities often occupy the leftover old houses and apartments which are usually located in the central cities (O’Sullivan, 2003). The data screening in Sacramento County shows that the average housing age in the neighborhoods with a high ratio of blacks is higher than that in the neighborhoods with fewer blacks. Therefore, average housing age is expected to have a direct impact on job accessibility. In this study, the average age of all housing units will be used as a measure of average housing age. No evidence shows that average housing age will affect income, employment ratio, or auto ownership, although the correlations may exist.

Impacts of Median Rent. Median rent is expected to affect people’s residential location choices and thus job accessibility. No evidence shows that median rent will affect income, employment ratio, or auto ownership, although correlations may exist.

Impacts of Single Headed Households. Some empirical studies (Blumenberg and Ong, 1998; Blomenberg and Shiki, 2003) find that single headed households have higher unemployment rates than non-single headed households. In this study, as an exogenous variable, single headed households, which is measured as the percentage of single headed households in a census tract, is expected to have a negative impact on employment ratio. It will not affect auto ownership, job accessibility, or income.

3.1.4 Empirical Test of the Conceptual Model

This conceptual model can be solved with cross sectional data at the aggregate level in commercial structural equation modeling software, such as AMOS and LISREL. Tables 2 and 3 list the endogenous variables and exogenous variables and how they are calculated. The models will be estimated for pooled data, pooled blacks, pooled whites, poor blacks, and poor Whites separately.

Table 2 Endogenous variables

Name	Definition
Employment ratio	Employment ratio = (The number of workers in each tract)/(The number of people aged 16 to 64 in each tract)
Income	Median household income
Auto ownership	Percentage of households that can access at least one car
Job accessibility	(1) Raphael (1998)’s method based on employment counts (2) Job accessibility based on travel model

Table 3 Exogenous variables

Name	Definition	Affected endogenous variables
Competing labor supply	Total persons who age 16-64 and can access the jobs in a census tract	Employment ratio
Education	Percentage of persons with college degree	Employment ratio; income
Household size	Average household size	Auto ownership
Car insurance premium	Annual car insurance premium	Auto ownership
Transit availability	Ratio of transit accessibility to car accessibility ¹	Auto ownership
Rental housing density	Rental housing units divided by total housing units	Job accessibility
Average housing age	Average age of all housing units in a census tract	Job accessibility
Median rent		Job accessibility
Single headed households	Percentage of single headed households	Employment ratio

3.2 Unconditional Change-Score Model of the Spatial Mismatch Hypothesis

The unconditional change-score model was originally used in multiple regression analyses with panel data. It assumes that the relationships between dependent variables and independent variables hold over time. In other words, the coefficients of the independent variable at time t will have the same sign and magnitude as those at time $t - 1$ (Finkel, 1995). This model is superior to the cross-sectional model in several ways. First, it measures the impacts of changes in the independent variables on the dependent variable(s) directly. In an unconditional change-score model, the change of a variable is the difference of its values measured at two time points in the same panel. In a cross-sectional model, the changes are either not measurable or measured as inter-unit changes due to the limitations of cross-sectional data. The determinants of change of the dependent variable derived from a cross-sectional model are weaker in addressing the causality. Second, the impacts of the independent variables, regardless of whether they are observed, with constant effects are crossed out. In other words, some variables have constant impacts on dependent variables over time and do not explain any changes in the dependent variable. Third, an unconditional change-score model does not have to take into account cross impacts of independent variables at time $t-1$ on dependent variables at time t . Although an unconditional change-score model is generally applied in multiple regression

analysis, its premise is also applicable to structural equation modeling. Figure 2 is constructed according to this idea.

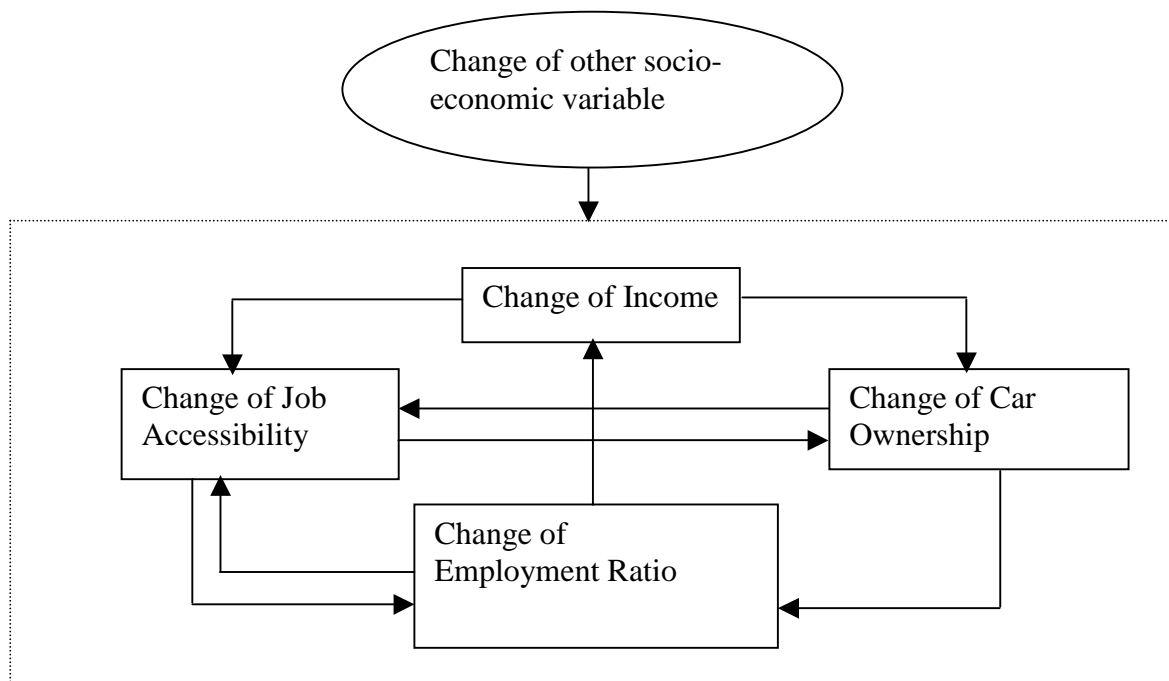


Figure 2 Unconditional change-score conceptual model of the SMH

In an unconditional change-score SEM, all the relationships between endogenous variables and between endogenous variables and exogenous variables can be examined in the form of change. The relationships between job accessibility and employment ratio will be paid extra attention. In this model, the change of job accessibility is interpreted as net growth of job opportunities. If job growth, not job level, matters to employment ratio, then the growth of job accessibility will increase the change of the employment ratio. Combining the results from the cross-sectional SEMs, we will be able to determine which measure of job accessibility has a more significant impact, job level or job growth.

3.3 Dynamic Structural Equation Model of the Spatial Mismatch Hypothesis

One important assumption in an unconditional change-score SEM is that the observed values of endogenous variables at Wave I (time t) have no lagged effects on the values at Wave II (time $t+1$). Whether the lagged effects exist or whether the lagged effects can be ignored is testable by using a conditional change-score SEM (See Figure 3), which is a dynamic SEM. In a dynamic SEM, the observed values of endogenous variables at Wave II will be affected not only by exogenous variables and other endogenous variables at Wave II, but also by the observed values of the endogenous variables at Wave I. To simplify the model and make model identification easier, we assume that there are no cross impacts of endogenous variables at Wave I on the endogenous variables at Wave II. Another important assumption is that there are no

cross impacts between the endogenous variables at Wave I. The two assumptions may not be true in the real world, but will largely simplify the model identification process.

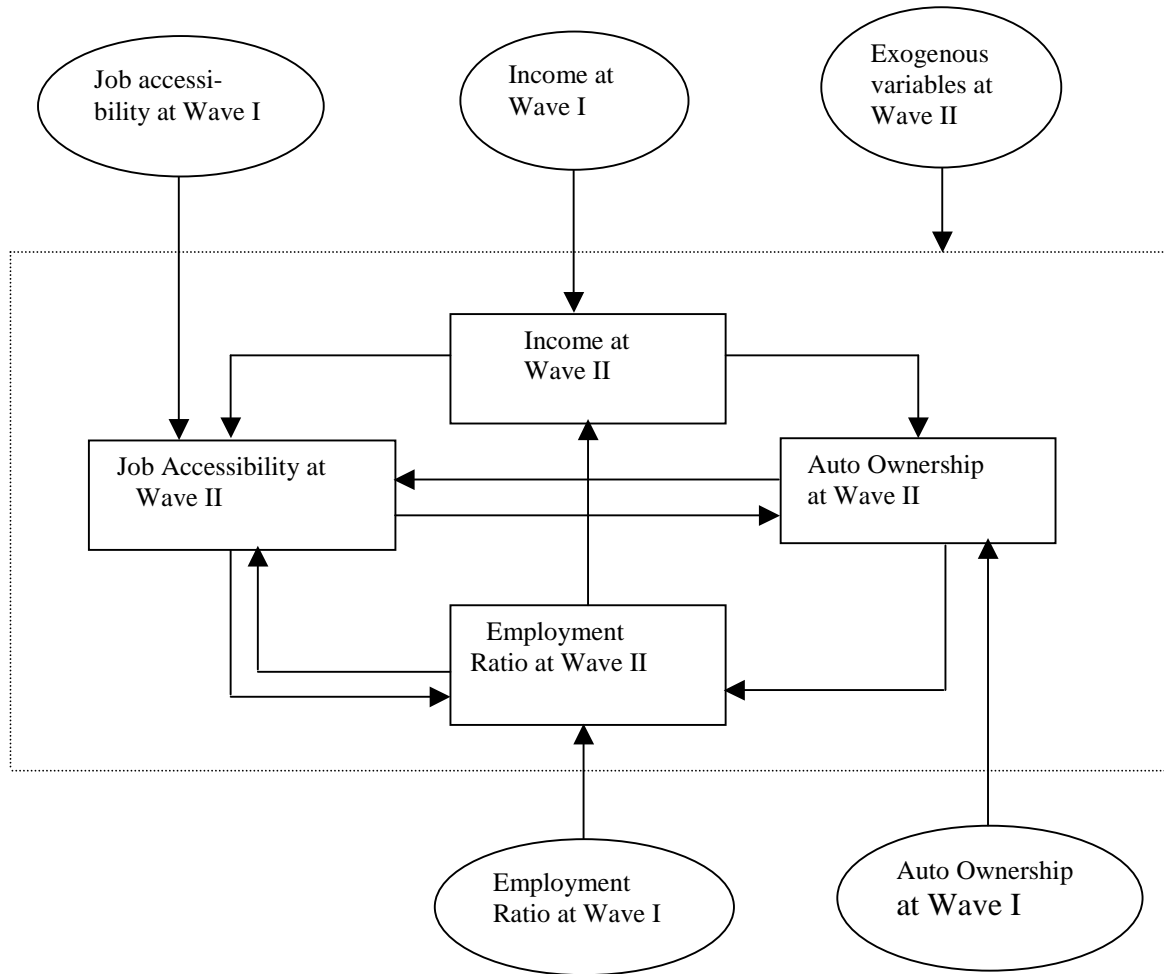


Figure 3 Dynamic structural equation model of the SMH

4. CONCLUSIONS

In the spatial mismatch context, the endogeneity of residence, as well as the endogeneity of auto ownership, are thought to exist, but have never been statistically proven. The conventional multiple regression models and logistic regression models cannot deal with endogeneity. Therefore, the estimates in these models are not reliable. Structural equation modeling is superior to the conventional modeling methods in terms of its ability to remove endogeneity bias through integrating job accessibility, employment ratio, and auto ownership

into a simultaneous equation system. This ability also makes structural equation modeling not subject to sampling bias, because we can use complete Census datasets.

The cross-sectional model tests the impacts of the endogenous and exogenous variables, and the endogeneity of residence and auto ownership. The unconditional change-score model tests the impacts of job growth. The dynamic model tests the lagged impacts of endogenous variables. They consist of a powerful model series to test different dimensions of the SMH. The data for testing the models are available for most cities. Therefore, rather than being just conceptual models, they are all testable.

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