The Impacts of Transport Accessibility on Population Change across Rural, Suburban, and Urban Areas: A Case Study of Wisconsin at Subcounty Levels

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Abstract A large body of research has found that highways and airports have played important roles in promoting population growth (or decline). However, little attention has been paid to the possible spatial variation of their effects on population change. This study uses data related to population change in 1980–1990 at the minor civil division level in Wisconsin to investigate the effects of highway and airport accessibility and accessibility improvements on population change across rural, suburban, and urban areas. The results show that the effects vary across the three area types. In rural areas, highway improvement and airport accessibility promote population growth; in suburban areas, airport accessibility promotes population growth but highway accessibility facilitates population flows; and in urban areas, neither highways nor airports have statistically significant effects on population change. The findings have important implications for local transportation planning, as highways and airports play different roles along the rural-urban continuum.

1 Introduction

Transportation infrastructure plays an important role in transforming society (Baum-Snow, 2010). Transport impacts on development and population growth (or decline) have been studied in several social science disciplines. However, the possible spatial variation of transport impacts on population change across rural, suburban, and urban areas has been seldom investigated. Spatial variation of the effects may exist because local areas vary in their growth mechanisms, areal characteristics, and temporal contexts (Partridge et al., 2008).

Here, the author attempts to fill this gap in the literature by examining the possible spatial variation of transport impacts on population change. Specifically, the author uses data related to population change in 1980–1990 at the minor civil division (MCD) level, a subcounty level, in Wisconsin to investigate the effects of highways and airports on population change. The effects are measured by accessibility to airports and highways and improvements in each. The variations in effects across rural, suburban, and urban areas are analyzed.

This article is organized into four additional sections: (1) a review of prior research on the effects that highways and airports have on population change and a framework for explaining the possible spatial variation of the effects; (2) a description of the data, the measures of highways and airports, the classification of the urban-rural continuum, and the analytical approach; (3) an examination and comparison of the effects of highways and airports on population change overall as well as across rural, suburban, and urban areas; and (4) a summary and discussion of the results.

2 Prior research

Transport impacts on population change have been addressed in Roback's (1982) general equilibrium model of firm and household location decisions, which suggests that transportation cost is an important determinant of location decisions for both firms and households. In order to achieve profit maximization, a firm chooses a location where transportation costs can be reduced and cost minimization and demand maximization can be achieved (McCann, 2001). Households prefer locations with low land costs and easy access to both high wage rates and urban amenities in urban areas and natural amenities in rural areas (Isserman, 2001). Convenient surface transportation allows people to live farther away from these amenity areas. Easy access to air travel provides additional advantages by opening access to opportunities in distant urban areas.

The impacts of highways and airports on development and population growth are obvious, but they may vary spatially because growth mechanisms, areal characteristics, and temporal contexts are likely to vary spatially across local areas (Partridge et al., 2008). Nevertheless, the potential spatial variation of transport impacts has rarely been studied, and the impacts of highways and airports on population growth have seldom been analyzed together.[1] Studying highway and airport impacts on population growth together could inform transportation planners of the relative importance of highway and airport investment in promoting local development. The three subsections that follow review the two separate lines of literature on highways and airports and discuss the possible spatial variation of transport impacts.

2.1 Highway impacts on population change

The literature that specifically examines highway impacts on population change is limited, mostly coming from the field of sociology (e.g., Chi, 2010a; Lichter and Fuguitt, 1980; Perz et al., 2010; Voss and Chi, 2006). However, research on employment change and, more broadly, on economic growth and development is vast, supported by several theories and numerous studies. Most relevant to this study are neoclassical growth theory (Solow, 1956), growth pole theory (Perroux, 1955), and central place theory (Christaller, 1966).

[1] A large body of literature compares the social costs of highway and airway transportation, generally concluding that highway transportation has much higher social costs than airway transportation. For a review of the literature, see Levinson, Gillen, and Kanafani (1998).

According to neoclassical growth theory, three basic inputs produce outputs: land, capital, and labor. Investments in highways are a type of public capital and can be seen as an input into the production process through a production function, which assumes a relationship between outputs and combinations of inputs (Eberts, 1990). Many neoclassical growth theory studies examine the connection between public capital and economic productivity through the production function (e.g., Dalenberg and Partridge, 1997). Applied to highways, this theory would predict that as the amount of highway infrastructure increases, economic output increases, which in turn leads to population and employment growth.

Growth pole theory uses the notions of spread and backwash to predict the mutual geographic dependence of economic growth and development between metropolitan areas and their surrounding rural areas, which in turn causes population change. Highways are seen as a catalyst of change (Thiel, 1962). Building a highway that links a metropolitan area and its surrounding areas is neither a necessary nor a sufficient influence for population growth in the two areas; population decline could also be an outcome.

Central place theory sees highway infrastructure as a facilitator for the flows of raw materials, capital, finished goods, consumers, and ideas between central locations and their neighborhoods (Thompson and Bawden, 1992). By this definition, highway infrastructure is a facilitator of population flows because it can promote population inflows as well as population outflows, depending on other influential factors and the overall population redistribution trends. Highways themselves, however, do not produce population change.

Numerous empirical studies at various geographic scales have yielded disparate and contradictory findings regarding highway impacts on population and economic change. For example, highways were found to promote population and economic growth in some studies (e.g., Boarnet, Chalermpong and Geho, 2005; Cervero, 2003; Goetz et al., 2010), and to have no effects or to be only a secondary factor in affecting population and economic growth in other studies (e.g., Hulten and Schwab, 1984; Jiwattanakulpaisarn et al., 2009; Voss and Chi, 2006).

The mixed views and findings may be a result of spatial heterogeneity of highway impacts.[2] Highway impacts on population change differ across rural, suburban, and urban areas (Chi, 2010a). The three area types have different demographic and socioeconomic characteristics, and residents in the three area types may perceive highways differently. In a study examining highway expansion impacts on population change in Wisconsin at the MCD level, Chi (2010a) found different impacts across rural, suburban, and urban areas: highway expansion has indirect effects on population change in rural areas, both direct and indirect effects in suburban areas, and no statistically significant effects in urban areas.

2.2 Airport impacts on population change

A large literature exists regarding airport impacts on economic growth and development (Goetz, 1992; Goetz and Sutton, 1997). The conventional wisdom is that airports play an important role in promoting economic growth and development. Similar to highways, airports can have both direct and indirect impacts on economic and employment growth (Kasarda and Lindsay, 2011). Airport operations themselves create job opportunities, such as those directly related to airport management and airline operations. Airport operations also create indirect job opportunities that provide supporting services, such as shopping vendors within the airport and hotels outside the airport. Airports could also bring in firms that benefit from fast delivery of their products or easy

[2] Two additional explanations for the mixed findings are that (1) highway impacts on population and economic growth vary across pre-construction, construction, and post-construction periods, and (2) the impacts may differ at different geographic scales. See Bhatta and Drennan (2003) and Boarnet (1997) for a detailed review of the literature.

national and international travel, and they may attract migrants who appreciate the convenience of long-distance travel that airports provide. Airport development can have important impacts on urban agglomeration, business competition, and job creation; this view has been addressed in the concept of *aerotropolis* (Kasarda and Lindsay, 2011).

However, this line of research focuses on economic and employment growth rather than population change. Airports could also play an important role in promoting population growth because population growth and employment growth are often highly correlated (Boarnet, Chalermpong, and Geho, 2005). Compared with surface transportation, such as highways and railways, airports provide more convenient long-distance travel. Airway travel reduces the distance limits on social and economic interactions (Irwin and Kasarda, 1991). Air transportation links cities together, increases the interactions between distant cities, and integrates otherwise isolated economic regions into a nationwide or worldwide economic region (Brueckner, 2003). Thus, airports increase intercity agglomeration and promote population change (Zipf, 1946).

Most studies of airport impacts on population and economic growth have been conducted in metropolitan areas and have found that airport activities promote population and economic growth. For example, Irwin and Kasarda (1991) studied the causality between airline networks and employment growth in U.S. metropolitan areas. They found that an airline network is a cause rather than a consequence of employment growth. Brueckner (2003) found that good airline service, as measured by passenger boardings, is an important factor in promoting urban economic growth. Green (2007) found that passenger boarding is a powerful predicator of population and employment growth in metropolitan areas.

A few studies have been conducted in rural areas, but the findings are mixed. For instance, Rasker et al. (2009) found that airport access plays a vital role in promoting economic development in high-amenity rural areas. Yet, Isserman, Feser, and Warren (2009) found that distance to major airports is relatively unimportant for economic development in rural areas.

Few studies have compared airport impacts on population and economic growth between metropolitan and nonmetropolitan areas (an exception is Reynolds-Feighan 2000). Airport impacts on population and economic growth may vary between metropolitan and nonmetropolitan areas, just as highway impacts differ across rural, suburban, and urban areas. Easy access to airports might be valued differently by migrants to rural, suburban, and urban areas; those who migrate to urban areas likely value urban amenities more (Fallah et al., 2011), but those who migrate to rural areas likely value natural amenities more (Partridge et al., 2008). An airport could be seen as a growth pole in the region it serves. Airport construction or expansion would change the equilibrium of urban hierarchy and induce population change across rural, suburban, and urban areas.

2.3 Spatial variations of the impacts

The spatial heterogeneity of population change has long been recognized in existing literature and has been found to be caused by accumulated human and physical capital, natural endowments, and economic geography (Wu and Gopinath, 2008). However, spatial heterogeneity of these factors' effects on population change has been largely ignored. Local areas may vary in their growth mechanisms in ways that are not readily captured in traditional global standard regression models (Partridge et al., 2008). The global estimates of coefficients can reflect the collective effects but not the local variations of the effects, which would provide misleading information of local dynamics. In this article, the author discusses the possible spatial heterogeneity of highway and airport impacts on population change across rural, suburban, and urban areas. The author attempts to form a framework for this study by building on existing literature.

Transportation generally has a positive effect on rural development by attracting migrants and promoting employment growth (Isserman, Feser, and Warren, 2009). Planners often use highway investment as an input to promote rural development, which is supported by neoclassical growth theory (Eberts, 1990). After new highway construction, rural areas that were previously beyond the reach of a metropolitan center are brought into its commutable distance. These rural areas then become attractive to both firms and migrants, which in turn promotes local population growth. For rural areas that already have highway access, improved highways can reduce the time to reach a metropolitan center, which again promotes local population growth. Easy access to airports plays a more important role than access to highways in promoting rural population growth, especially in remote rural areas (Rasker et al., 2009). Easy access to airports connects rural areas to nearby metropolitan centers as well as distant ones, exposing the rural areas to a larger market and creating more opportunities.

Suburban areas have long benefited from metropolitan growth and development, thanks to improvements in transportation infrastructure and innovation in transportation and communication techniques, proximity to urban areas, and relatively lower housing prices (Isserman, 2001). A convenient highway network permits suburban residence with convenient commuting to an urban area for work or for amenities such as shopping, health-care facilities, and entertainment centers. A convenient highway network also allows suburban residents to commute to access natural amenities in rural areas. Thus, highways encourage suburban residence, but they also facilitate population outflows from suburban areas, depending on the overall population and economic dynamics (Chi, 2010a). In contrast, proximity to airports likely has a positive effect on suburban growth: easy access to airports opens greater opportunities in more-distant metropolitan areas. Easy access to airports increases population dynamics between suburban areas and metropolitan areas at a much larger geographic extent.

Transport impacts on urban development are more complex than those on rural and suburban change (Chi, 2010a). Transportation infrastructure is seen as both an amenity and a disamenity in urban areas (Chi and Parisi, 2011). It is an amenity because it provides easy access to opportunities in other areas and increases population dynamics. It is a disamenity because it brings environmental pollution such as noise, dirt, and fumes to the immediate and nearby neighborhoods; and it creates "crime" spaces people want to avoid. Transportation infrastructure thereby reduces housing values in the immediate neighborhoods. Population change in urban areas is further complicated by land use regulations and policies. In short, transport impacts on urban population change are uncertain because they can either promote or hinder urban development, depending on many other factors as well as the spread and backwash effects of the growth pole theory (Boarnet, 1997).

The exploration into the possible spatial variation of transport impacts on population growth is based on Roback's (1982) general equilibrium model, Zipf's (1946) notion of intercity agglomeration, neoclassical growth theory (Solow, 1956), growth pole theory (Perroux, 1955), and central place theory (Christaller, 1966). These competing theories of transport impacts on population change are all "correct," each one being best applied to different regions and locations. Using these theories as a foundation, the author aims to investigate the possible spatial variation of transport impacts—of both highways and airports—on population growth across rural, suburban, and urban areas.

3 Data, measures, and analytical approach

This study focuses on the state of Wisconsin as the research case and investigates the impacts of highways and airports on population growth from 1980 to 1990 at the MCD level. The population data used in this study are from the decennial census. The analytical data set consists of 1,837 adjusted MCDs, with an average size of 29.56 square miles. The MCDs, which are county subdivisions (Wisconsin has 72 counties), are non-nested, mutually exclusive, exhaustive political territories. Wisconsin is a typical MCD state—one composed of low-density rural areas; many small villages, towns, and cities; and a few large cities and surrounding neighboring suburbs. Each MCD (a city, a village, or a town) is a functioning governmental unit with elected officials who provide services and raise revenues. MCDs are designated on the basis of legal entities rather than on population sizes, and are recognized in 28 U.S. states.

Studying transportation impacts on population change at subcounty levels, such as the MCD level, can provide insights into the possible local dynamics that may not be captured by analysis at the county level or higher. A change in transportation accessibility can have greater impacts on population change at subcounty levels than at county and higher levels. When the local changes are aggregated from finer scales to larger ones, the changes may offset each other. This phenomenon—the scale effect (Fotheringham and Wong, 1991)—would be more obvious in metropolitan areas, where a county is likely divided into several MCDs. For example, highway expansion or construction would be unpleasant to the immediate neighborhoods but would benefit neighborhoods a few blocks away (Chi and Parisi, 2010). Similarly, airport expansion would be unpleasant to the immediate areas but would benefit nearby areas. In both cases, immediate neighborhoods or areas would experience population loss or lower population growth compared with those nearby, but the internal migration would have less impact on total population change in their home county.

The impacts of highways and airports on population change are measured on the basis of the accessibility that they provide.[3] Highway and airport accessibility in this study were measured in 1980, and accessibility improvements were measured for the period 1980–1990. Thus, this study uses four major explanatory variables: highway accessibility as of 1980, improvement in highway accessibility from 1980 to 1990, airport accessibility as of 1980, and improvement in airport accessibility from 1980 to 1990. These four measures and their data sources are described in the following sections.

3.1 Highway accessibility and improvement

Highway accessibility is measured as the natural log of highway density—that is, the total lengths of highways in an MCD divided by the MCD's geographic area as of 1980 (Eq. 1). The higher the highway density is, the more access to highways a MCD has and, therefore, the higher its accessibility becomes. This measure of highway accessibility has been used widely because of its low data requirements. For example, the World Bank has used road density for measuring road accessibility in each country (Black, 2003).[4] In this study, highway lengths in each MCD are calculated using spatial overlay and data conversion functions in ArcGIS on the basis of a highway network file from the National Atlas of the United States, which includes limited-access highways, principal highways, and secondary or through highways.

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[3] A small body of literature has examined passenger intermodal transportation, in which passengers optimize the use of both highways and airways to reach their destinations (e.g., Combes and Linnemer, 2000; Paez, 2004). This literature has often measured the intermodal impacts by calculating the accessibility that highways and airways can collectively best provide.

[4] A more accurate measure of highway accessibility might be the number of highway exits or intersections located in each unit (Black, 2003). This measure could be considered in future studies.

$$\text{Highway accessibility} = \log(\text{Highway density}) \qquad (1)$$

Highway investment, as reflected by highway segment expansion during the period of 1980–1990, provides additional (or improved) accessibility. Although not all MCDs experienced highway expansion during 1980–1990, those closer to expanded highway segments benefited more than those farther from expansions. A shorter distance from an MCD to a highway expansion segment means improvement to highway accessibility. The improvement of highway accessibility is measured by a distance decay function: the natural log of the inverse squared distance to the nearest expanded highway segment (Eq. 2; Fig. 1).

$$\text{Highway improvement} = \log\left(\frac{1}{d_h^2}\right), \qquad (2)$$

where d_h represents the distance to the nearest highway segment that was expanded during 1980–1990.

[FIG. 1 ABOUT HERE]

The highway expansion data from 1980–1990 were provided by the Wisconsin Department of Transportation. The data were initially available in a hard copy document listing the road segments that were expanded, the five-year periods in which they were expanded (e.g., 1980–1985, 1985–1990), and where each expansion segment started and ended. These expansion segments were also highlighted on paper maps. Based on this information, the road expansion segments were coded into a geographically referenced database.

3.2 Airport accessibility and improvement

Accessibility to airports is measured as a function of the distance from an MCD to its nearest airport as well as the airport's passenger boardings (including both the number of passengers departing from an airport via plane and the number of passengers who switch from one plane to another) in 1980 (Eq. 3). The closer a MCD is to its nearest airport, the greater the accessibility the MCD has to the airport; and the higher the nearest airport's number of boardings, the greater the accessibility the MCD has to other regions via the airport. This accessibility measure builds on Hansen's (1959) definition of accessibility, which considers both the costs to access destinations and the opportunities in those destinations. Some studies have measured airport accessibility as distance to the nearest airport (Isserman, Feser, and Warren, 2009) or travel time to nearest airport (Rasker et al., 2009). Others have measured airport impacts by airport importance, such as airport centrality (Irwin and Kasarda, 1991), and airport activities, such as passenger boardings (Brueckner, 1998; Green, 2007) and the number of routes or destinations offered (Neal, 2010); the latter two measures are highly correlated because a higher number of passenger boardings reflects more frequent services to a variety of destinations.[5] In this study, airport accessibility, which is measured as a combination of the distance to the nearest airport and its boardings, considers both accessibility and importance.

$$\text{Airport accessibility} = \log\left(\frac{1}{d_a^2} \times Boardings_{1980}\right), \tag{3}$$

where d_a represents the distance to the nearest airport and $Boardings_{1980}$ represents the number of passenger boardings at the nearest airport in 1980.

The airports selected for this research are the commercial service airports in Wisconsin as well as those close to Wisconsin but located in its neighboring states (Fig. 1), for a total of 16 airports. The passenger boarding data were provided by the Federal Aviation Administration as

[5] The social network literature provides various approaches for measuring airport activities. Airport centrality and the number of routes or destinations offered could be incorporated into the measure of airport accessibility in future research as data become available. See Neal (2010) for a review of airport accessibility measures.

well as several states' aviation offices: the Wisconsin Bureau of Aeronautics of the Department of Transportation, the Iowa Office of Aviation of the Department of Transportation, the Illinois Division of Aeronautics of the Department of Transportation, the Michigan Bureau of Aeronautics and Freight Services of the Department of Transportation, the Minnesota Office of Aeronautics of the Department of Transportation, the O'Hare International Airport, and the Duluth International Airport.

The improvement of airport accessibility is measured as a function of both the inverse squared distance to the nearest airport and the airport's passenger growth rate during 1980–1990 (Eq. 4). The closer a MCD is to a commercial airport, the greater accessibility the MCD has to that airport. Also, the greater the passenger growth rate[6] for the nearest airport, the greater the improvement of the airport's accessibility, since a higher passenger growth rate reflects increased airport activities, which is an indirect indicator of the improvement of airport accessibility to other regions.

$$\text{Airport improvement} = \log\left(\frac{1}{d_a^2} \times \frac{Boardings_{1990}}{Boardings_{1980}}\right) \tag{4}$$

3.3 Control variables

This study includes a number of control variables in the models. These variables are related to sociodemographic characteristics, economic conditions, rurality, and land use and development. Sociodemographic characteristics include *young* (percentage of the population aged 12–18), *Bachelor's degree* (percentage of the population [aged ≥25] with bachelor's degrees), and *female-headed families* (percentage of female-headed families with children under 18 years old).

[6] The passenger boarding growth rate during 1980–1990 is measured as a ratio rather than as a difference of the two years' boardings due to the logarithm function: if boardings in 1990 were higher than those in 1980, the natural log of the ratio results in a positive value, corresponding to boarding growth; if boardings in 1990 were lower than those in 1980, the natural log of the ratio results in a negative value, corresponding to boarding decline.

Economic conditions are measured by *unemployment* (unemployment rate) and *income* (median household income). Rurality is measured by *public water* (percentage of housing units using public water), *agriculture* (percentage of workers in agricultural industry), and *seasonal housing* (percentage of seasonal housing units). Land use and development are measured by *population density* (persons/kilometers squared), *commute time to work* (percentage of workers traveling >30 minutes to work), and *land developability* (percentage of lands available for development; see Chi [2010b] for details). These control variables are used and discussed in detail in Chi (2010a).

3.4 The classification of rural, suburban, and urban areas

To examine the potential spatial variation of transport accessibility impact on population change, this study classifies MCDs as rural, suburban, and urban by following Chi (2010a)'s categories that combine the U.S. Census Bureau's 1990 Urbanized Areas (U.S. Census Bureau, 2004) and the U.S. Office of Management and Budget (2003) classifications (see Fig. 2). A total of 86 urban MCDs represents the largest cities in Wisconsin. There are 417 suburban MCDs, which are not the largest cities but are located within metropolitan areas. Further, 1,334 rural MCDs are located outside of metropolitan areas. Refer to Chi (2010a) for detail of the classification. This typology, which generally corresponds to the three primary regional types of urban, suburban, and rural that are used in many regional economic studies, is meant to be an intuitive representation of the rural-urban continuum.

[FIG. 2 ABOUT HERE]

The classification also reasonably represents the range of MCD types from rural to suburban to urban, as supported by the descriptive statistics of the variables used in this study (Table 1).

First, the population size increases and the geographic size decreases from rural to suburban to urban areas. Second, population growth rates in the three areas as they are categorized here correspond to the general population redistribution trends in Wisconsin. In the 1970s, Wisconsin's population growth was greater in rural and suburban areas than in urban areas; in the 1980s, the state's population growth was greater in urban areas than in suburban areas, and greater in suburban areas than in rural areas (Voss and Chi, 2006). These historical trends are reflected in the data for these categories shown in Table 1.

[TABLE 1 ABOUT HERE]

Third, transportation accessibility and improvement correspond to the characteristics of the three types of MCDs. All four transportation measures increase from rural to suburban to urban areas. Finally, demographic characteristics, socioeconomic conditions, and land developability generally support the corresponding characteristics of rural, suburban, and urban areas. Educational attainment, income, and the proportion of housing units using public water increase from rural to suburban to urban areas. The proportion of agricultural workers and seasonal housing units decrease from rural to suburban to urban areas. The proportion of female-headed families with children was the highest in urban areas.[7]

3.5 Analytical approach

This study uses measures of highway and airport accessibility and their improvements to examine highway and airport impacts on population change. First, this study employs basic ordinary least squares (OLS) models to analyze and compare the global impacts of highways and

[7] Although this classification of MCDs represents the urban-rural continuum reasonably well, a finer classification system could identify differences among rural areas. For example, remote rural areas differ greatly from rural areas that are adjacent to metropolitan cities. Future research could use a finer classification by comprehensively considering population density, population size, adjacency to the largest cities, and the socioeconomic contexts of each MCD.

airports on population change. This study then uses spatial regime models to examine the variations of the impacts across rural, suburban, and urban areas.[8] The spatial regime models estimate coefficients separately for each regime (Anselin, 1990); in this study, the models assume that three regimes exist: one each for rural, suburban, and urban areas. Coefficient stability for each variable can then be diagnosed by the spatial Chow test. Alternatively, spatial heterogeneity could be addressed by using the geographically weighted regression (GWR) method (e.g., Ali, Partridge, and Olfert, 2007). Although GWR provides an elegant means of modeling the spatially varying coefficients, the resulting coefficients are estimated to vary continuously. Here, the present research considers only three distinct area types whose coefficients more likely differ distinctly. Therefore, this study uses the spatial regime model rather than the GWR method for investigating the possible spatial heterogeneity of transport impacts on population change.

4 Findings

4.1 Overall impacts on population change

The impacts of highways and airports on population change are examined in three OLS regression models (Table 2). Model 1 compares the impacts of highway accessibility and highway accessibility improvement on population change during the period 1980–1990.[9] Highway improvement has significant impacts on population change, but highway accessibility

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[8] Spatial regression models that formally incorporate spatial process effects have been used in studies of highways and population change. For example, Chi (2010a) used spatial lag models, spatial error models, and spatial error models with lag dependence to study highway impacts on population change. In this study, however, the measures of highway and airport accessibility and improvement themselves are spatial measures and also consider the spatial effects from neighboring states (Michigan, Minnesota, Iowa, Illinois, and Indiana). Thus, instead of these spatial regression models, this study uses spatial regime models to examine the spatial variations of highway and airport impacts on population change.

[9] The results cannot suggest causality from highways and airports to population change, but rather an association between them. However, "associated with" and "affect" or "have effects on" are used interchangeably in this article.

does not. Model 2 compares the impacts of airport accessibility and airport accessibility improvement on population change. Airport accessibility has significant impacts on population change, but airport improvement does not. Model 3 compares the impacts of both highway and airport accessibility and improvements in accessibility. Only airport accessibility plays a significant role in promoting population growth.

[TABLE 2 ABOUT HERE]

Overall, airport accessibility has the strongest impact on population growth in 1980–1990. Highway improvement plays a significant role in promoting population growth only when airport accessibility is not considered. Highway accessibility and airport improvement have no impacts on population growth during 1980–1990.

The impacts of highways and airports on population change may differ spatially because local dynamics may vary in terms of growth mechanisms, areal characteristics, and temporal contexts. Next, the author turns to the impacts of highways and airports on population change across rural, suburban, and urban areas in spatial regime models. The author discusses these results, shown in Table 3, in the next three subsections.

[TABLE 3 ABOUT HERE]

4.2 Impacts in rural areas

In rural areas, both highway improvement and airport accessibility are associated with population growth from 1980 to 1990. Highway improvement acts as an investment to promote rural population growth. As mentioned previously, neoclassical growth theory considers highway improvement to be an input into the production process via a production function: as highway investment increases, outputs also increase. However, highway accessibility does not have effects on rural population growth, possibly because highway impacts on population growth diminish after highway construction is completed (Voss and Chi, 2006).

Airport accessibility is associated with population growth in rural areas. This finding contrasts with that of Isserman, Feser, and Warren (2009), who argue that distance to major airports is relatively unimportant for rural areas. However, the finding of this study is consistent with that of residential preference studies, which have found that rural areas that are closer to airports are preferred residential areas (e.g., Fuguitt and Brown, 1990). These rural areas have the locational advantages of access to nearby metropolitan areas as well as to metropolitan areas in other regions, and thus are often preferred for residence over other rural areas.

Improvement in airport accessibility, as measured by passenger growth and access to airports, has no association with population growth. This finding contrasts with studies concluding that passenger growth and population growth are simultaneous (e.g., Green, 2007). The different results may be due to scale effects: passenger growth may have an effect on population growth at a larger geographic level than the MCD.

4.3 Impacts in suburban areas

In suburban areas, highway accessibility is negatively associated with population growth. Highways seem to facilitate out-migration. As mentioned previously, central place theory sees highways as a facilitator for the flows of raw materials, capital, finished goods, consumers, and ideas among central places and their neighborhoods (Thompson and Bawden, 1992). Highways are further argued to be a facilitator of population flows (Chi, 2010a): highways can be associated with both population growth and population decline. From 1980 to 1990, Wisconsin experienced the slowest growth in its history, and highways might have helped facilitate population outflow. Highways themselves do not promote or hinder population change; they only promote population flows.

Improvement in highway accessibility, which is measured as a highway investment variable, is not associated with suburban population growth. Suburban growth is affected by a variety of factors, such as easy access to both rural and urban areas, decent housing prices, and low crime rates (Baum-Snow, 2007). Highway investment is, at most, a secondary factor in promoting suburban growth.

Airport accessibility, however, is positively associated with suburban population growth. Suburban areas have the locational advantages of access to both urban amenities and rural amenities, and they also have relatively lower housing prices than urban areas (Isserman, 2001). Furthermore, suburban areas that are close to airports benefit more from population interaction and intercity agglomeration by providing convenient access to cities in other regions. Thus, suburban areas that are close to airports are more attractive than those that are not.

4.4 Impacts in urban areas

In urban areas, none of the four accessibility measures is associated with population change from 1980–1990. There are three possible explanations. First, highway and airport impacts on population change in urban areas are complex; highways and airports can either help or hinder the development of urban areas, depending on many other factors as well as the net effects of spread and backwash (Boarnet, 1998). Second, the findings may be limited because of the scale effect—that is, highways are seen as a noise and pollution producer by immediate neighborhoods but are seen as providing accessibility by neighborhoods just a few blocks away (Chi and Parisi, 2011). Thus, it may make more sense to study highway effects at block or block group levels.

Airports could also be viewed unfavorably in immediate neighborhoods yet may be appreciated by residents in a larger geographic extent. Therefore, it may make more sense to study airport effects at larger geographic levels, such as counties. Third, population change in urban areas is volatile to land use planning and regulations (Chi, 2010a). Population change is complicated by zoning regulations and divisions of land use, such as residential, commercial, and other developments. Because of these many factors, highways and airports are less important factors in affecting population change in urban areas.

5 Summary and discussion

5.1 Summary

Many studies have found that highways and airports play important roles in promoting development and population change. However, the potential spatial variations of their effects were seldom examined, and their effects were mostly studied separately. This study uses data related to population change in 1980–1990 at the subcounty's minor civil division level in Wisconsin to investigate and compare the effects of highway and airport accessibilities as of 1980 as well as of accessibility improvements from 1980 to 1990 on population change across rural, suburban, and urban areas. This study fills the gap in the literature by contributing to the understanding of the roles that highways and airports play in affecting population change along the rural-urban continuum.

Overall, the results show that although airport accessibility and highway improvement are associated with population change, highway accessibility and airport improvement are not. The results also show that the effects vary across rural, suburban, and urban areas. In rural areas, highway improvement is an investment input to promote population growth, and airport accessibility promotes growth by providing convenient access to other regions. In suburban areas, airport accessibility promotes population growth by increasing regional population interaction, but highway accessibility facilitates population flows. In urban areas, highways and airports do not have statistically significant effects on population change, possibly owing to scale effects and constraints on land use policies and regulations.

5.2 Policy implications

The findings of this study have important implications for local transportation planning, as highways and airports play different roles across rural, suburban, and urban areas. A universal strategy for the best utilization of transportation investment to promote local growth and development does not exist. Local areas should consider their growth mechanisms (e.g., sociodemographic characteristics and economic conditions), areal characteristics (e.g., rurality and land use and development), and temporal contexts (e.g., population redistribution pattern) in making transportation investment decisions.

In rural areas, highway investment, whether in the form of highway construction, expansion, or improvement, is still a good planning tool for promoting growth and development. New or improved highways in rural areas reduce cost and time involved in transporting raw materials (or finished goods) into (or out of) the region and provide convenient commuting to metropolitan cities. These benefits, in turn, attract firms and migrants to the region. Although most rural areas lack resources for financing highway investments, they could explore federal and state programs and maximally seek these outside resources. This strategy can be rewarding in the current economic recovery period because the federal government has emphasized transportation investment as a way to recover economic growth.

In addition, accessibility to airports is also an important factor in promoting rural growth and development. The lack of airways is often a hindrance in attracting firms, which require more frequent interaction with distant regions in modern society (Kasarda and Lindsay, 2011). Easy access to airports encourages firms to move to rural areas, which in turn leads to employment and population growth. Although it is infeasible to have commercial airports for every MCD or county, several nearby areas could work together to build a commercial airport with the permission and financial assistance from federal and state governments. This is especially important for remote rural areas, where commercial airports are not available or are too far to access. When remote rural areas become easily reachable through airways, the appreciation of the areas' resources, such as natural amenities, can be materialized.

In suburban areas, proximity to airports is an important factor in promoting growth and development. Residents living in suburban areas tend to have received better education, have relatively higher ranks in their organizations, and have higher than average incomes (Wu, 2010). These people are more likely to travel long distances for business and personal leisure. Thus, easy access to airports becomes essential because airports connect suburban residents to more opportunities that are not constrained by geographic distance. Increasing airport accessibility should be one of the priorities in suburban transportation planning. Although building a new airport is not easy, options such as increasing flight service (e.g., more frequent flights to the same destination, flights to more destinations, and more airlines) in nearby airports could be considered. Regarding highways, highway accessibility facilitates population flows in suburban areas yet may not promote population growth. Highways not only bring people in but also take people out, depending on the general population redistribution trend. If transportation planners in suburban areas want to promote growth and development, highway investment (that is, beyond an adequate level of maintenance) is not an effective option.

In urban areas, neither highways nor airports play an important role in promoting growth and development at the MCD level, for two possible reasons. One reason is related to the scale effect. Highway impacts may be better studied at finer geographic levels because highways are seen as a disamenity to immediate neighborhoods but as an amenity to neighborhoods just a few blocks away. In contrast, airport impacts may be better studied at a regional level because an airport serves an area much larger than an MCD. The other reason is that development in U.S. urban areas may already have reached maturity; investment on highways and airports in urban areas creates growth and development in surrounding areas but not in the urban areas. Thus, transportation planners in urban areas should focus more on optimizing their existing transportation infrastructures by building efficient passenger intermodal transportation systems, reducing traffic congestion, increasing transportation equity, and adopting other options that can increase the quality of life in urban areas (Pucher, 2004).

The preceding discussion is limited to growth and development within each area type. Some of the proposed strategies would bring benefits for one area type but may become barriers for the other area types. A more systematic analysis of the spatial variation of transport impacts on population growth would enable a more optimal allocation of resources at the federal and state levels to promote growth and development across rural, suburban, and urban areas.

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Fig. 1. Highway Expansions from 1980 to 1990 in Wisconsin and Major Airports in Wisconsin and Neighboring States

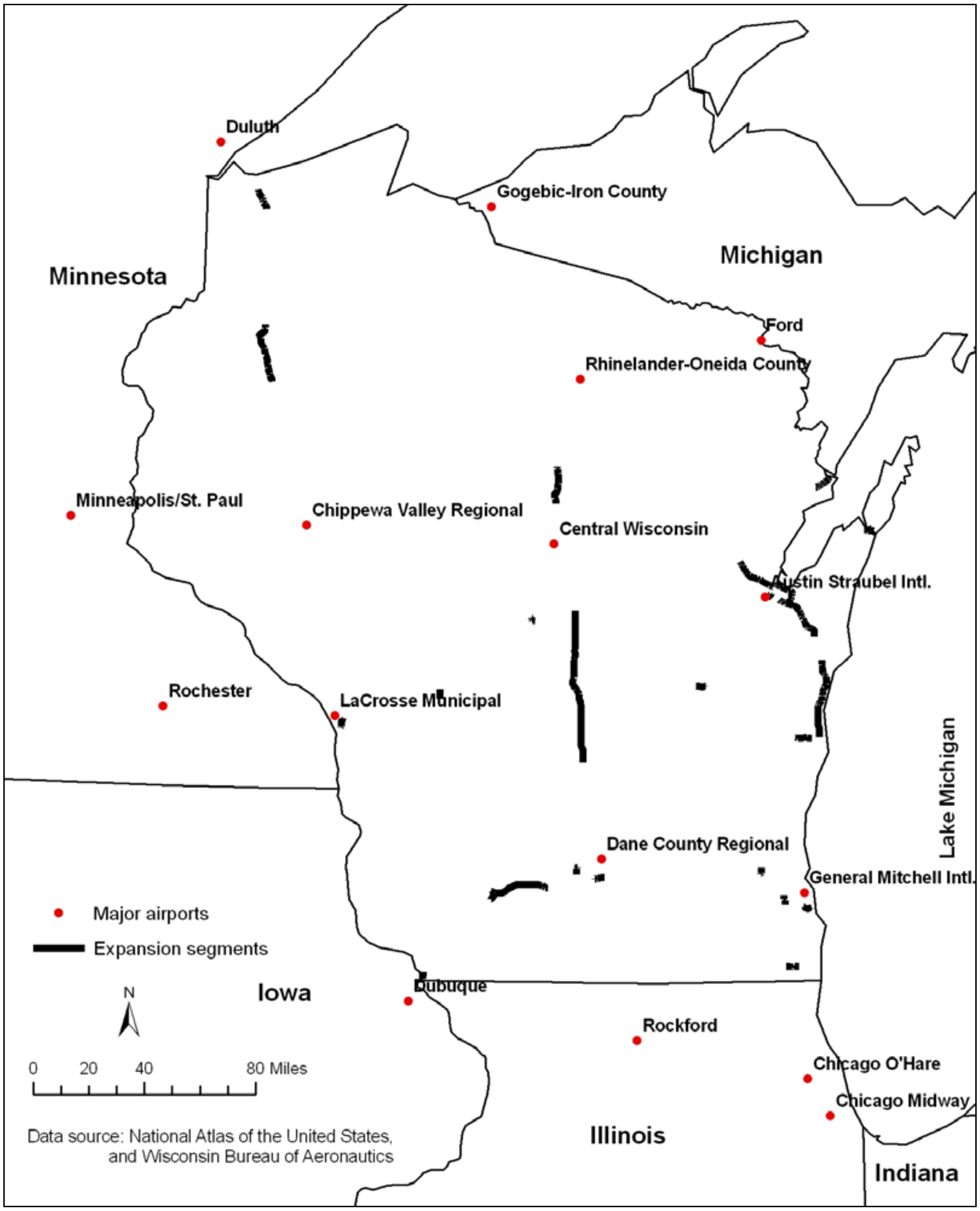

Fig. 2. The Classification of Rural, Suburban, and Urban Minor Civil Divisions in Wisconsin

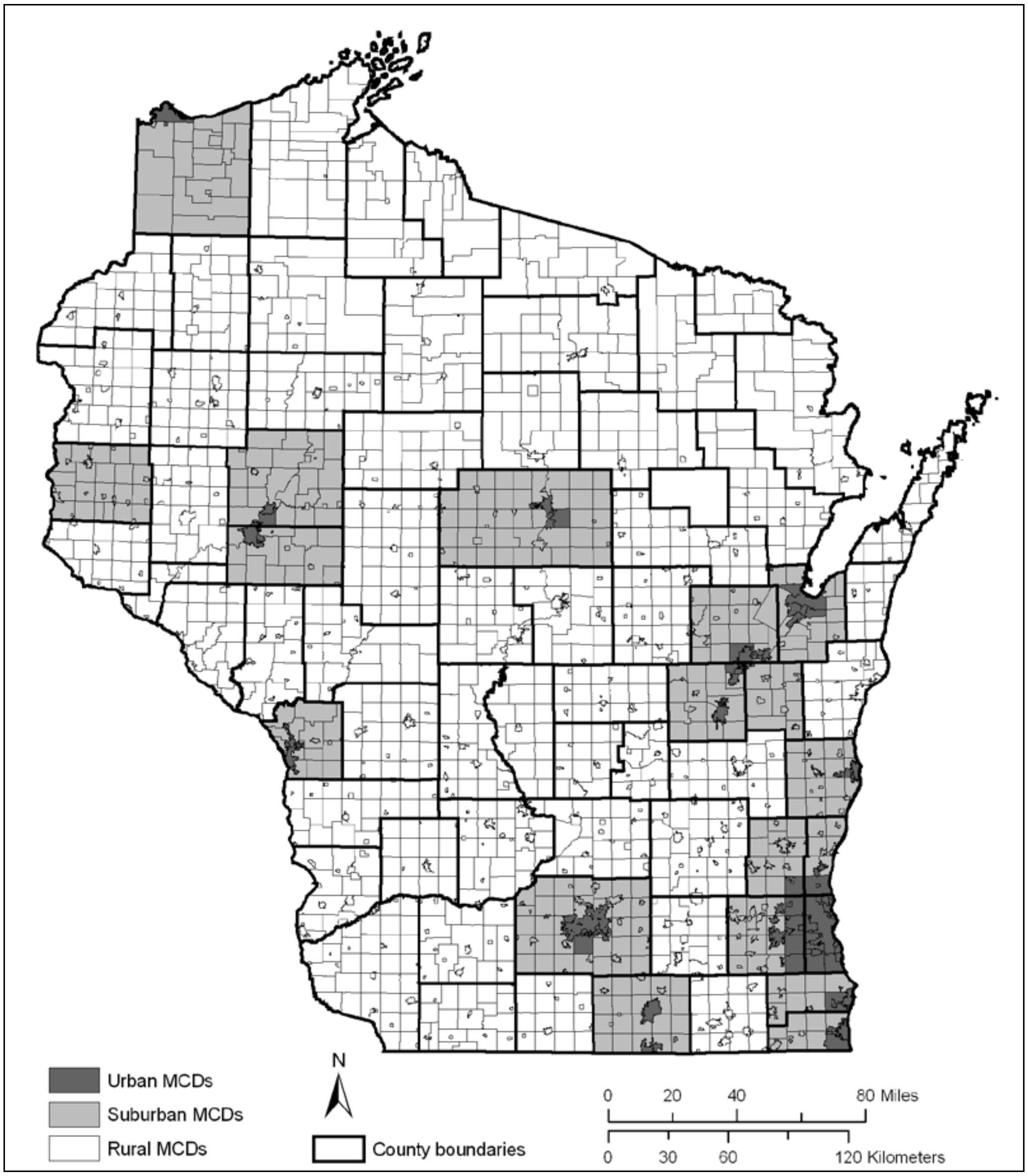

Table 1. Descriptive Statistics of Variables

	All	Rural	Suburban	Urban
Population size in 1990	2,663	1,197	2,136	27,964
	(16,458)	(2,220)	(2,404)	(71,151)
Geographic area (kilometers^2)	79.068	84.497	70.157	38.068
	(69.592)	(73.551)	(55.755)	(44.785)
Population density (persons/kilometer^2)	123.389	85.296	110.824	775.186
	(251.410)	(157.239)	(166.875)	(622.789)
Population growth rate in 1980–1990	0.020	0.008	0.048	0.074
	(0.129)	(0.120)	(0.143)	(0.152)
Population growth rate in 1970–1980	0.174	0.165	0.207	0.162
	(0.262)	(0.246)	(0.290)	(0.335)
Highway accessibility	0.822	0.753	0.874	1.644
	(0.527)	(0.475)	(0.468)	(0.786)
Highway improvement	–5.781	–6.088	–5.281	–3.443
	(1.931)	(1.732)	(1.975)	(2.482)
Airport accessibility	5.043	4.426	6.330	8.378
	(1.866)	(1.451)	(1.666)	(1.807)
Airport improvement	–6.665	–7.002	–5.998	–4.671
	(1.148)	(0.841)	(1.205)	(1.511)
Young	0.138	0.135	0.146	0.133
	(0.027)	(0.027)	(0.023)	(0.024)
Bachelor’s degree	0.097	0.086	0.110	0.212
	(0.066)	(0.048)	(0.066)	(0.139)
Female-headed families	0.079	0.080	0.068	0.122
	(0.051)	(0.052)	(0.038)	(0.058)
Unemployment	0.082	0.086	0.075	0.052
	(0.048)	(0.050)	(0.039)	(0.027)
Income	$15,999	$14,466	$19,428	$23,134
	($4,658)	($3,287)	($4,262)	($8,019)
Public water	0.276	0.247	0.257	0.818
	(0.398)	(0.380)	(0.391)	(0.294)
Agriculture	0.164	0.184	0.131	0.007
	(0.156)	(0.161)	(0.131)	(0.007)
Seasonal housing	0.087	0.107	0.039	0.002
	(0.148)	(0.161)	(0.088)	(0.004)
Commute time to work	0.231	0.225	0.268	0.140
	(0.137)	(0.138)	(0.135)	(0.070)
Land developability	0.725	0.720	0.788	0.500
	(0.192)	(0.187)	(0.162)	(0.213)
Number of MCDs (*N*)	1,837	1,334	417	86

Note: Each cell contains a mean, followed by a standard error in parentheses.

Table 2. Ordinary Least Squares (OLS) Regressions of Transport Impacts on Population Change, 1980–1990, at the MCD level in Wisconsin

	Model 1	Model 2	Model 3
Highway accessibility	0.009	/	0.005
	(0.005)		(0.005)
Highway improvement	0.003*	/	0.002
	(0.001)		(0.001)
Airport accessibility	/	0.018***	0.017***
		(0.002)	(0.002)
Airport improvement	/	–0.004	–0.004
		(0.003)	(0.003)
Young	–0.881***	–0.860***	–0.860***
	(0.121)	(0.120)	(0.120)
Bachelor's degree	0.035	0.077	0.077
	(0.053)	(0.053)	(0.053)
Female-headed families	–0.028	–0.028	–0.037
	(0.070)	(0.068)	(0.069)
Unemployment	–0.148*	–0.091	–0.087
	(0.067)	(0.067)	(0.067)
Income	3.46E–6***	3.27E–7	1.32E–7
	(9.22E–7)	(9.89E–7)	(9.99E–7)
Public water	0.028*	0.028*	0.029*
	(0.012)	(0.011)	(0.011)
Agriculture	–0.161***	–0.126***	–0.124***
	(0.026)	(0.026)	(0.026)
Seasonal housing	0.103***	0.108***	0.109***
	(0.023)	(0.023)	(0.023)
Population density	–5.45E–5**	–7.07E–5***	–7.54E–5***
	(1.67E–5)	(1.63E–5)	(1.66E–5)
Commute time to work	0.034	–0.004	–0.000
	(0.021)	(0.020)	(0.021)
Land developability	0.040*	0.038*	0.037*
	(0.017)	(0.016)	(0.016)
Constant	0.081**	–0.002	0.010
	(0.029)	(0.0404)	(0.042)
Measures of fit			
Log likelihood	1405.21	1434.81	1436.52
AIC	–2782.42	–2841.61	–2841.05
BIC	–2705.20	–2764.39	–2752.79

Note: **p* ≤ .05; ***p* ≤ .01; ****p* ≤ .001
Robust standard errors are in parentheses.
AIC = Akaike's Information Criterion; BIC = Schwartz's Bayesian Information Criterion.

Table 3. Spatial Regime Regressions of Transport Impacts on Population Change, 1980–1990, at the MCD level in Wisconsin by Rural (R), Suburban (S), and Urban (U) Areas

	Model 1				Model 2				Model 3			
	R	S	U	Instab	R	S	U	Instab	R	S	U	Instab
Highway accessibility	0.011	–0.020	0.018	*	/	/	/		0.010	–0.025*	0.021	*
	(0.007)	(0.012)	(0.018)						(0.007)	(0.012)	(0.018)	
Highway improvement	0.004*	–0.004	0.008		/	/	/		0.004*	–0.006	0.011	**
	(0.002)	(0.003)	(0.006)						(0.002)	(0.003)	(0.006)	
Airport accessibility	/	/	/		0.014***	0.017**	–0.022		0.014***	0.018***	–0.042	*
					(0.003)	(0.005)	(0.020)		(0.003)	(0.005)	(0.022)	
Airport improvement	/	/	/		–0.007	0.002	0.024		–0.007	0.004	0.038	*
					(0.004)	(0.006)	(0.019)		(0.004)	(0.006)	(0.020)	
Young	–0.970***	–0.361	–1.819**		–0.916***	–0.509	–1.804**		–0.914***	–0.507	–1.972**	
	(0.131)	(0.326)	(0.703)		(0.131)	(0.324)	(0.696)		(0.130)	(0.323)	(0.698)	
Bachelor’s degree	0.051	0.148	–0.123		0.081	0.145	–0.244		0.075	0.140	–0.336	
	(0.071)	(0.118)	(0.149)		(0.069)	(0.120)	(0.179)		(0.070)	(0.120)	(0.185)	
Female-headed families	–0.041	–0.113	–0.329		–0.034	–0.132	–0.273		–0.047	–0.123	–0.356	
	(0.076)	(0.202)	(0.355)		(0.075)	(0.200)	(0.355)		(0.075)	(0.200)	(0.355)	
Unemployment	–0.102	–0.421*	0.041		–0.071	–0.213	–0.922		–0.072	–0.258	–0.907	
	(0.074)	(0.170)	(0.696)		(0.073)	(0.172)	(0.849)		(0.073)	(0.172)	(0.850)	
Income	1.37E–6	4.71E–6*	9.41E–7		–5.65E–7	2.12E–6	1.30E–6		–1.08E–6	2.35E–6	4.17E–6	
	(1.24E–6)	(2.26E–6)	(3.32E–6)		(1.31E–6)	(2.41E–6)	(3.54E–6)		(1.33E–6)	2.41E–6)	(3.71E–6)	
Public water	–0.005	0.104***	0.147*	***	–0.007	0.098***	0.132*	**	–0.004	0.093**	0.134*	**
	(0.015)	(0.029)	(0.062)		(0.015)	(0.029)	(0.061)		(0.015)	(0.029)	(0.061)	
Agriculture	–0.158***	–0.160*	4.703*		–0.133***	–0.079	5.240*	*	–0.133***	–0.105	4.682*	
	(0.029)	(0.068)	(2.335)		(0.029)	(0.068)	(2.259)		(0.029)	(0.068)	(2.304)	
Seasonal housing	0.092***	0.159*	1.407		0.096***	0.174*	0.749		0.096***	0.190*	0.923	
	(0.024)	(0.078)	(3.078)		(0.024)	(0.079)	(3.021)		(0.024)	(0.079)	3.052)	
Population density	–5.36E–5	–3.06E–5	–5.55E–5		–4.38E–5	–2.17E–5	–4.14E–5		–5.75E–5	–2.72E–5	–2.01E–5	
	(3.48E–5)	(6.27E–5)	(3.08E–5)		(3.40E–5)	(6.28E–5)	(3.25E–5)		(3.44E–5)	(6.26E–5)	(3.59E–5)	
Commute time to work	–0.018	0.134**	0.133	**	–0.040	0.111*	0.248	**	–0.036	0.095*	0.394	**
	(0.024)	(0.043)	(0.200)		(0.024)	(0.044)	(0.235)		(0.024)	(0.044)	(0.242)	

Land developability	0.045*	0.040	0.168	0.047*	0.041	0.179	0.040*	0.046	0.208*	
	(0.019)	(0.043)	(0.102)	(0.018)	(0.042)	(0.101)	(0.018)	(0.043)	(0.102)	
Constant	0.131***	–0.056	0.131	0.018	–0.099	0.469	0.049	–0.098	0.640*	*
	(0.035)	(0.071)	(0.176)	(0.052)	(0.084)	(0.300)	(0.055)	(0.085)	(0.313)	
Measures of fit										
Log likelihood		1459.16			1476.21			1486.89		
AIC		–2834.33			–2868.41			–2877.78		
BIC		–2602.66			–2636.75			–2613.02		

Note: *$p \le .05$; **$p \le .01$; ***$p \le .001$
Robust standard errors are in parentheses.
AIC = Akaike's Information Criterion; BIC = Schwartz's Bayesian Information Criterion; Instab = Instability.