Filling the Gaps: Dentist Disparities along the Rural Urban Continuum

Terance J. Rephann and Tanya N. Wanchek*

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Abstract

This paper examines the distribution of dentists among U.S. counties along the rural-urban continuum. Dentist workforce availability has implications for oral health care access and utilization, which in turn can affect the quality of life, health, and productivity of rural residents. In addition, dentists form part of the non-tradable services sector, and its erosion may affect the vitality of rural economies. Nonmetropolitan counties have significantly lower levels of dentists per 100,000 residents than metropolitan areas and face the prospect of future attrition in the dentist workforce because of an aging workforce and increasing difficulty attracting newly minted dentists who favor more urbanized practice locations. The paper develops spatial econometric models of dentist location to help identify factors amenable to policy intervention. Results indicate that demand factors such as income, private insurance coverage, educational levels, and demographic composition play a role in dentist disparities. Also, private practice dentists tend to cluster near counties with urban areas consisting of at least 10,000 residents, higher net in-commuting, a greater presence of other health care and creative class professionals, and natural amenities. More stringent regulation for dental hygienists also boosts the relative quantity of dentists. Dental schools and public dentists are associated with a greater availability of private practice dentists.

Keywords: dentists, distribution, spatial econometrics, rural-urban continuum

*Center for Economic and Policy Studies, Weldon Cooper Center for Public Service, University of Virginia, Charlottesville, VA 22903

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1 Introduction

Regional labor markets are key to the growth and development of regional economies. Therefore, considerable attention has been paid to the mechanics of regional labor markets by examining issues such as migration, commuting, and human capital/skill acquisition (Isserman et al. 1987; Johnson 2006). Since regional labor markets contain workers from the same profession, some researchers have focused their attention at an occupational level to better understand the distributional characteristics and locational choices of high-skilled professions such as medical doctors, scientists, artists, and even veterinarians. Such highly educated individuals play an increasingly important role in regional competitiveness at the same time that they show an increasing affinity for urban lifestyles (Florida 2002; Olfert et al. 2012).

This paper examines the regional distribution of dentists. This stereotypically staid vocation may not figure prominently in the creative class pantheon, but it is nonetheless important from both economic and analytical perspectives. First, the availability of dentists may have an effect on oral health care access. Access to dental services may affect the quality of resident oral health, which in turn, can have a significant impact on the quality of life, overall health, and the productivity of local residents. It may also form part of a bundle of local characteristics with amenity value that influences the locational choices of migrants. Second, dentists form a part of the economic base of small towns throughout the United States. The attrition or loss of local dentists as with other health professionals and leakage of dollars up the urban hierarchy would have a small but negative impact on rural economies (Doeksen et al. 1998). Third, recent data indicates that disparities between metropolitan and nonmetropolitan areas in dentists per capita are growing and some rural areas are beginning to see a loss of dentists. These disparities are likely to grow at least in the immediate future because a relatively large proportion of the rural dental workforce is nearing retirement age at the same time that more demographically diverse youthful graduate cohorts are exhibiting a marked preference for more urbanized practice locations. Fourth, the dentist market is quite different from most occupations examined in the regional science literature in terms of demand drivers, the role of public policy, and influence of rapidly changing profession demographics in choice of practice location. Therefore, it presents an interesting case study of a migrant that differs from the generic regional migrant assumed in more aggregate regional modeling.

Regional health workforce issues have long been within the purview of public health researchers. However, most studies of dentist distributional characteristics have incorporated economic theory and spatial economic factors in a limited way if at all (Saman et al. 2010;Wall and Brown 2007;Krause et al. 2005; Nainar and Feigal 2004; Mertz and Grumbac 2001;Lowell-Smith 1993). They have also generally restricted their attention to localities within one state or states within the nation, making broader geographical generalizations about small areas difficult. One of the tools developed by public health researchers for professional workforce planning is the Dental Health Professional Shortage Area (dHPSA), which is a geographical region thought to have a deficit of dentists. dHPSA boundaries are determined by a formula that places heavy weight on population as a determinant of demand and secondary weight on proximity to available dental services in nearby areas.[1] Areas designated as dHPSAs have more than doubled from December 2001 to July 2011 from 1,853 to 4,661 with concomitant increases in the underserved population from 38.5 million to 52 million. Indeed, efforts to reduce the dentist disparities, heavily reliant on workforce strategies such as recruitment, retention, and education, continue to be confounded by the dentists themselves who disproportionately choose to locate in areas with more dentists. With market forces paramount in shaping dentist location decisions, it is important to know realistically how much of the dentist disparity can be lessened by such strategies and how much would require more sweeping reforms such as augmenting the purchasing power of dental customers through public dental insurance or dramatically expanding the dental safety net.

This paper is divided into several sections. The first section examines the regional distribution of dentists with a focus on locational patterns measured along the rural-urban continuum. The second section reviews the economic and public health literature on the determinants of dentist supply and demand. The third section describes the empirical model. The fourth section presents the model estimation and simulation results. The final section contains a summary and conclusion.

2 Dentist Distribution on the Rural Urban Continuum

Health workforce to population ratios provide one gauge of possible health service access disparities. The average professionally active dentist to population ratio nationwide was 64.7 per 100,000 residents in 2007. However, 255 counties did not have a single professionally active dentist. Moreover, significant disparities exist across the rural-urban continuum. **Figure 1** shows the distribution of both professionally active dentists (i.e., public and non-profit sector dentists plus dentists in private practices) as well as dentists in private practice by rural-urban continuum category, which runs from low values (counties in highly urbanized metro areas) to high values (non-metropolitan counties with less urbanization). Two patterns stand out. First, the dentist to population ratio is generally greater in urban and suburban counties than rural counties. The most rural of the continuum categories have fewer than half of the relative number of dentists as the larger metro area categories. Second, the disparities for dentists in private practice are lower. These dentists are likely to be more responsive to local demand characteristics. Part of the reason for the lower relative number of private practitioners in more rural areas is the existence of specialty care (see

[1] The designation criteria are described at: Health Resources and Services Administration, Bureau of Health Professions. http://bhpr.hrsa.gov/shortage/hpsas/index.html

Figure 1: Professionally Active and Private Practice Dentists per 100,000 Population by Rural-Urban Continuum Category, 2007

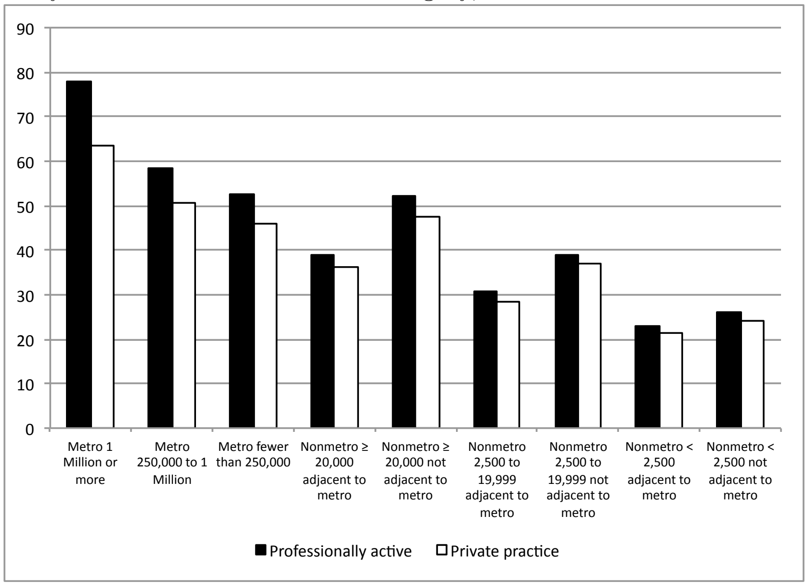


Figure 2). Relatively few dental specialists (e.g., orthodontists, oral surgeons, periodontists, endodontists) operate in rural markets because they must draw from a larger catchment area to maintain a profitable practice and will tend to locate in more centralized urban locations. Even after accounting for these specialists, there is still a sizable disparity.

Figure 3 shows that disparities have grown over the previous decade for both professionally active and private practice dentists with large metro counties gaining the most dentists on a per capita basis. Only one rural-urban continuum category (Completely rural or less than 2,500 urban population, adjacent to a metro area) actually saw a slight decrease in dentists. These disparities are likely to grow worse before they become better. **Figure 4** shows that non-metro counties, particularly those down the rural-urban continuum have a much higher percentage of dentists in the retirement age (65+ years) and near retirement age (55-64 years) groups and proportionally fewer young dentists. This pattern may be partly related to graduate locational preferences. Recent cohorts of dental school graduates have indicated a preference for more urban or suburban practice locations. For instance, only 5.2 percent of recent graduating seniors stated that they intend to practice in an area with less than 10,000 population (Okwuje et al. 2009). The changing demographics of dental school graduates which reflect a higher proportion of females (see **Figure 5**) and Asians may also intensify the propensity for graduates to locate in metropolitan areas.

Health workforce to population ratios such as the ones used here have been

Figure 2: Private Practice Generalists and Specialists per 100,000 Population by Rural-Urban Continuum Category, 2007

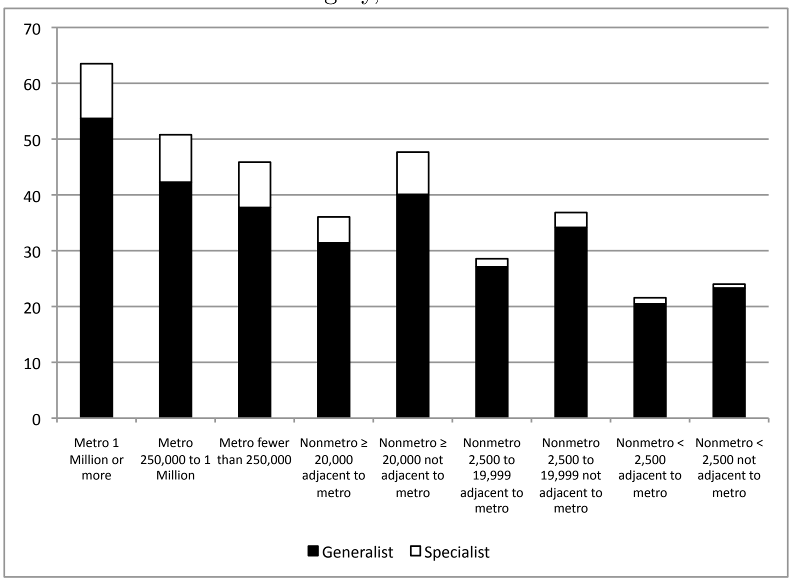


Figure 3: Change in Professionally Active and Private Practice Dentists per 100,000 Population by Rural-Urban Continuum Category, 1998-2007

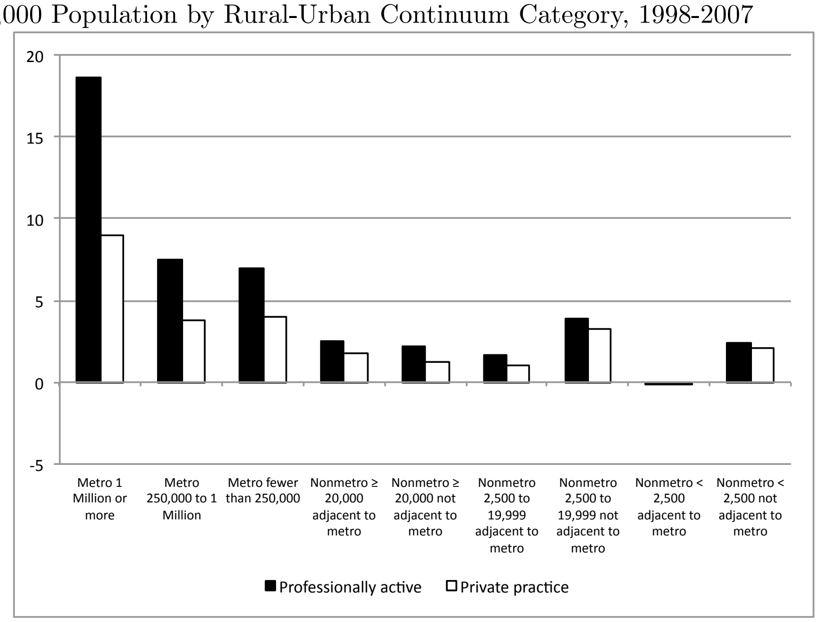


Figure 4: Percentage of Private Practice Dentists by Age Group and Rural-Urban Continuum, 2007

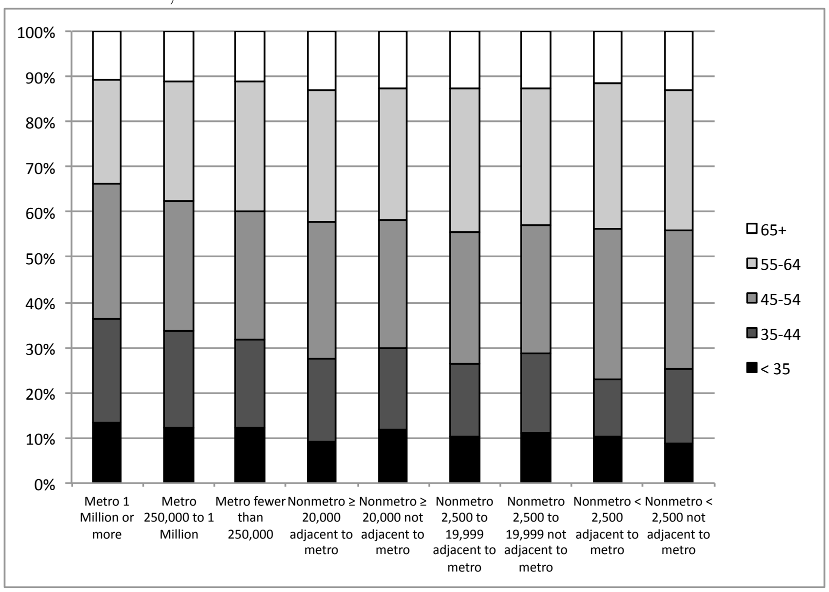
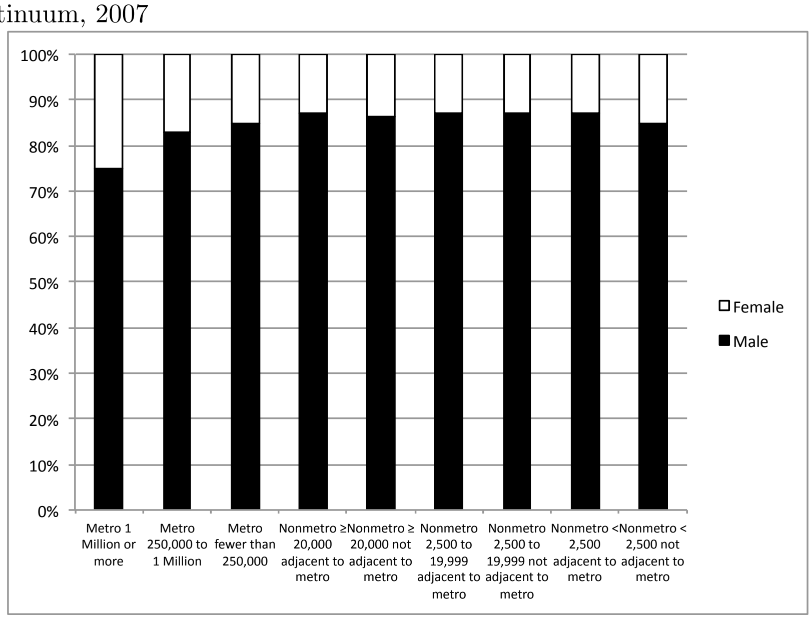


Figure 5: Percentage of Private Practice Dentists by Gender and Rural-Urban Continuum, 2007



criticized for providing a misleading gauge of workforce inadequacies (Wade and House 2008; Rosenthal et al. 2005; Hong and Kindig 1992; Newhouse et al. 1982). The very term "inadequacy" implies that the need for dental services is not being met in an area, and defining inadequacy by population ratio implicitly assumes that the only determinant of need is the size of the population. But the need for dental professionals in an area only has meaning in relation to the services that would actually be purchased if the services were available, in other words, the demand for the services. And it is well understood that the demand for dental services depends on much more than just a population headcount. For example, regional disparities in income levels and dental insurance coverage affect the demand for dental services. Differences in citizen education levels, water supply fluoridation, and demographic variables may also help explain differences in demand. To know whether the supply of dentists is adequate, we need to know the demand for the services; to know what to do about a perceived inadequacy, we need to know what is limiting the supply.

Likewise, the regional supply of dental services or the supply side of the dental services equation, is determined by more than just the number of dentists. Supply is affected by input costs and productivity differences at alternative locations. For instance, dental offices located in more urbanized areas may experience urbanization economies that result from greater scheduling flexibility due to customers traveling to the site for work and shopping along with lower costs for specialized inputs such as business services and dental auxiliaries. If identifiable demand/supply factors such as these are responsible for the disparities in dentist distribution, policymakers would have more success trying to alter these regional demand and supply characteristics than simply increasing the supply of providers.

3 Literature Review

In a market-driven system, where private practice dentists choose to settle depends in large part on the opportunities to operate a profitable practice and hence on the income and population characteristics of the region as well as the number and characteristics of competing providers of services in the region. Also, consumption opportunities and non-consumptive good availability such as natural amenities may be important. The starting point for this discussion is a stylized model of the health care professional location decision along the lines of Goetz and Debertin (1996)and Olfert et al. (2012) in which a representative dentist selects a location based on maximizing utility among competing jurisdictions over a set of composite goods (Z), area amenities (A_j), and government services (G_j). The dentist maximizes a utility described by:

$$U = U(Z, A_j, G_j) \tag{1}$$

This utility is constrained by a budget characterized as:

$$Pz_j Z = Y_j - T_j \tag{2}$$

where Pz_j is the price of the composite good which varies by area, T_j is jurisdiction taxes, and Y_j is income potential. (1) and (2) can be combined to produce an indirect utility function:

$$V_j = V(Y_j, Pz_j, T_j, A_j, G_j) \tag{3}$$

Income (or profit) potential will vary based on area consumer demand characteristics (Q_j), state regulatory and education policies that affect dentist entry and competition (R_j), availability of public dentist providers (U_j), and the dental market characteristics of proximate jurisdictions (N_j). Features of consumer demand considered here include area population (P_j), economic characteristics reflecting resident dental services purchasing power (E_j), resident dental care preferences and oral health status (O_j), and geographical location variables capturing transportation access costs (C_j).

Therefore, private-practice dentists will select locations on the basis of the following variables:

$$V_j = V(P_j, E_j, O_j, C_j, R_j, U_j, N_j, Pz_j, T_j, A_j, G_j) \tag{4}$$

This equation motivates the following discussion which focuses on these determinants with the goals of identifying important measurement variables for use in further empirical analysis.

3.1 Determinants of Dental Services Demand

3.1.1 Insurance and Income

Slightly over half of U.S. residents had private dental insurance in 2004 (Manski and Brown 2007). By reducing the cost of care, dental insurance influences the decision to seek dental services. Having private dental coverage significantly increases the likelihood of individuals to visit a dentist (Manski and Brown 2007). Furthermore, among people with a dental visit in the last year, having insurance was associated with more visits per year and higher dental expenditures (Manski et al. 2002). The generosity of coverage also matters. Unlike medical insurance, dental care routinely requires a substantial out-of-pocket payment. Mueller and Monheit (1988) found that dental services utilization and expenditures increased significantly as cost sharing declined. In general, insurance had a pronounced effect on the use of more expensive dental care such as prosthodontics. Dental insurance, however, had little or no effect on the use of preventive care.

The link between public dental insurance and utilization is much weaker. Medicaid is the most common form of public dental insurance, but it usually provides comprehensive coverage only for children through age 20. Medicare for seniors does not include dental coverage. Enrollment and utilization are low for Medicaid dental insurance in most states. Nationally, among the children without dental insurance, approximately 3 million were likely eligible for public insurance but had not enrolled (Lewis et al. 2009). Among those enrolled, often only 20 to 30 percent of children actually receive dental care in a given year. These low utilization rates have several explanations. Medicaid reimbursement rates for dentists serving Medicaid recipients are, in most states, significantly below usual and customary dental fees, reducing the number of dentists willing to serve Medicaid patients. Dentists also cite administrative difficulties and an excessive number of broken appointments as reasons for not accepting Medicaid patients (Bailit 2010). In fact, Medicaid utilization rates are typically not related to the absolute number of dentists in a county, but rather to the number of dentists accepting Medicaid patients (Bailit 2010). This suggests that simply increasing the number of providers may not be sufficient to increase use of dental services in undeserved areas.[2]

Income is also important. Although higher income families are much more likely to have dental insurance, when one compares families without dental insurance at various income levels, those with higher incomes are more likely to report a dental visit (Manski et al. 2002).

3.1.2 Tastes and Oral Health Status

People vary in their tastes and preferences for good oral health. Dental anxiety may curtail demand for some individuals. Educational achievement probably affects awareness of the benefits of dental care and may make it possible to lower the costs of obtaining dental care. Studies have found lower perceived need for care in rural areas and among individuals with a low socioeconomic status, which may be due to the social environment and expectations for good teeth. Family environment, particularly among children, is an important factor in health outcomes. Isong et al. (2010) found that whether a parent visited a dentist was strongly correlated with whether the child also had a dental visit. Similarly, Martin et al. (2008) examined the oral health status of children and adults in two rural West Virginia counties and found that among children there was a lower recognition of need, which could be due to a lower preference or expectations of good oral health outcomes.

Age also plays a role in the demand for oral health care services. The elderly tend to have low utilization rates. In 1999, 53.5 percent of adults 65 and older reported visiting a dentist, the lowest percentage of any adult age group (Kiyak and Reichmuth 2005). While costs are a factor, even when services are available at a free or reduced cost or when insurance is available utilization only increases

[2]Some states have developed innovative Medicaid programs that have dramatically increased utilization rates. For example, in 2000, Michigan implemented a Medicaid program, Healthy Kids Dental, where in select counties a private insurance carrier, Delta Dental, administered the program and reimbursed dentists at the private rate. The result of the program was to increase utilization by 31.4 percent overall and 39 percent among continuously enrolled children (Eklund et al. 2003). Furthermore, the program resulted in a substantial increase in dental participation and a decline in the distance between providers and the children receiving care.

slightly (Kiyak 1987). Low income and less-educated elders have been found to have lower expectations of good health in their old age (Kiyak and Reichmuth 2005). As a result, they are often more accepting of pain as a normal part of aging rather than an indicator of the need for oral health care. On the hand, seniors have the highest average annual expense among all age groups (Institute of Medicine and National Research Council 2011), reflecting the need for much costlier dental services when care is obtained.

As one would expect, an immediate need for care as measured by presence of tooth pain or gum bleeding has been found to be associated with a greater likelihood to seek care (Yule and Parkin 1985). Less obviously, a very low state of dental health may actually lower an individual's need for care. While poorer quality dentition on average might indicate greater need for care, lost teeth no longer need preventive care and costly restoration procedures over an individual's lifetime. This is one reason why studies investigating the effect of community water fluoridation on dental demand have been inconclusive. Although fluoridation is effective in reducing decay, it results in the retention of more teeth, which could increase the need for care during a person's lifetime (Yule and Parkin 1985).

3.1.3 Time and Travel Costs

Time spent traveling to care and waiting on service can also reduce utilization. The empirical evidence on the importance of these costs is inconclusive (Sintonen and Linnosmaa 2000). Measuring the effects is complicated by the fact that individuals often bundle their purchases of dental services with other goods and services and that provider prices may vary in response to expected wait times (Wade and House 2008). Probst et al. (2007) examined travel times for dental care and found that rural residents traveled 31.4 percent further and the trips took longer (27.2 minutes versus 20.7 minutes). By comparison, travel time to work was the same for rural and urban populations (23.5 minutes). The cost of travel time to dentists in rural areas is partly offset by the lower opportunity cost of time. Wages, which are the opportunity cost of visiting a provider during working hours, tend to be lower in rural areas. As a result the cost of the extra travel time is at least partially offset by the lower opportunity cost of time.

3.2 Determinants of Dentist Supply

3.2.1 Amenities

Amenities are known to influence regional migration flows. Natural amenities such as climate and features of the natural landscape (e.g., lakes, mountains) are usually counted (Graves 1980; McGranahan 1999). More recent work surrounds aspects of the built environment such as historical buildings, bike paths, and parks and cultural and entertainment amenities like restaurants, bookstores, art galleries and museums (Florida 2002). These amenities are thought to be especially important for members of the so-called creative class, workers in knowledge fields and the professions, who have more independence in their locational choices. The health professions are no different in this regard. Numerous studies call attention to the fact that dentists and other health care professions favor more urbanized locations and are either willing to either trade off urban amenities for income or able to take advantage of principal-agent information asymmetries and "induce demand" for their services in their preferred location (Dussault and Franceschini 2006; Goetz and Debertin 1996; Cromwell and Mitchell 1986).

3.2.2 Taxes and Public Services

State and local government taxation has a direct effect on after-tax income and should affect dentist locational choices holding all else constant. Evidence suggests that that property taxes and income taxes generally decrease in-migration (Fox et al. 1989). How the revenue is spent also matters. Higher expenditures on education have amenity value that has been found to attract in-migrants (Fox et al. 1989). Members of the professions may be expected to place an even higher premium on education quality. In the rare instances that tax and fiscal variables have been used to model health care profession distribution, the results have been mixed. Carpenter and Neun (1999) indicate that young physicians are drawn to counties with low per capita taxes. Goetz and Debertin (1996) find that the tax variables have statistically insignificant effects but educational spending is positively related to the primary care physician quantity. Mistretta (2007) shows a positive relationship between per capita school expenditures and physician practice location for specialists but a negative relationship for family physicians.

3.2.3 Dental Education

States have traditionally played a major role in funding dental education as a means to increase the supply of dentists in the state. In 2000, 36 states had public dental schools, providing an average subsidy of nearly $50,000 per dental student (Bailit and Beazoglou 2003). The effect of the subsidy, however, is not clear. Bailit and Beazoglou (2003) found that the level of state support for dental education actually had a negative association with the number of dentists per 100,000 residents, while the presence of a dental school had an insignificant effect. They argued that dentists locate primarily on the basis of demand for their services and, to a lesser extent, on where they were raised. This finding is supported by Bound et al. (2004), who found that in the health care sector, there was virtually no relationship between the state of degree production and employment. They find that the production of medical degrees tended to be concentrated in large, densely populated states and that MDs disperse across the country after degree completion. Dental schools may potentially serve as a magnet for practitioners on the local or regional level. Isabel and Paula (2010) review several studies that find that physicians have a higher propensity to locate near universities, especially ones where they attended. The authors provide several reasons for these findings, including personal attachments, professional relationships, and a desire for physicians to be close to centers of knowledge and innovation.

A number of studies have examined programs to increase the recruitment of health care professionals into rural and underserved areas, thereby creating a more equal distribution of providers throughout a state. Distribution of providers has been studied more thoroughly in the context of physicians than dentists, although many of the findings can be applied to the dental profession. A review of the literature by Brooks et al. (2002) found that, for medical students, having a rural upbringing and specialty preference for rural practice mattered. For schools a commitment to rural curriculum and rotations were the most significant factors in encouraging graduates to locate in rural areas. Similar results were found when UCLA/ Drew Medical Education Program students participated medical rotations in South Los Angeles, an impoverished urban area (Ko et al. 2007). Following the program, 53 percent were located in an impoverished or rural area after 10 years, compared with 26 percent of UCLA graduates, even after controlling for race and ethnicity.

3.2.4 Licensure and Regulation

Occupational licensure has been shown to be an important source of variation among states in the supply of dentists. Each state sets its own licensure requirements for both new dentists and for those moving into the state. Licensed dentists who wish to move to a new state, must obtain a license in that state. This process can be facilitated if states have reciprocity agreements, in which state dental licensing agencies agree to recognize the validity of each other's license, or if they have licensure by credential, in which states will grant licenses to practicing dentists who have met certain criteria, such as being in continuous practice for a specified period of time. States also vary significantly in both their entry requirements for dental hygienists, including what is required to obtain a licensure by credentials, and in their scope of practice restrictions, which range from allowing only basic teeth cleaning and polishing services to conducting more complex or potentially hazardous procedures, such as administering anesthesia and conducting restorative functions (Wanchek 2010).

There are both benefits and costs to occupational licensure. On the one hand, licensure is intended to reduce uncertainty for consumers by ensuring a minimum level of competency (Arrow 1971) or through greater standardization in care (Benham 1980). On the other hand, licensing may reduce supply by limiting entry into a market (Kleiner 2006). Licensing can also reduce quality by screening out the most qualified individuals. Individuals with a high opportunity cost may opt not to enter a profession because of the high cost of obtaining a license (Ballou and Podgursky 1998). An example is the case of teachers, where the large upfront cost of acquiring a teaching license may discourage entry of high-quality potential teachers who have many outside opportunities (Ballou and Podgursky 1998). Several studies of dentistry have examined the net effect of licensure on the supply of dentists. Boulier (1980) observed that lack of national reciprocity restricted dentist migration. States also regulate the level of supervision required by dentists of dental hygienists, ranging from direct supervision to complete autonomy. The consequence of restrictive scope of practice regulations is to increase the demand for dentists, while under-utilizing hygienists (Kleiner and Park 2010; DeVany et al. 1982).

3.2.5 Public Dentistry

The availability of public clinics (e.g., Federally Qualified Health Center dental clinics, health department clinics, dental school clinics) may boost the overall supply of local dentists. But, some portion of the services provided by public clinics will be in competition with those offered by private practitioners. Dentists who treat more than a few patients on public insurance, may suffer a loss of clientele that cannot easily be replaced by paying clients not on public insurance. On the other hand, an expansion of services available at no cost or very low cost will allow dentists who currently provide free services to reduce this money losing component of their practices because the patients unable to pay now have access to services elsewhere. Unfortunately, the dearth of research on this subject does not allow us to conjecture about the likely effects of publicly subsidized dental clinics on private practices. In one study, Kolimaga et al. (1994) find little effect of federally subsidized Community Health Centers on physician private practices located in the same service areas.

3.3 Spatial Dependence

There are grounds for suspecting that spatial dependence affects statistical analyses of health profession distribution. First, the administrative boundaries used for data collection such as states and counties may not reflect actual service areas (Goetz and Debertin 1996). Second, there may be underlying spatial processes such as spatial interaction, spatial diffusion, spatial spillovers, or central place hierarchies that shape local results. Indeed, the Health Manpower Shortage Area (HMSA) criteria for defining underserved areas recognizes the importance of spatial variables. Dental HMSAs must be "rational service areas" characterized by (a) travel times less than 40 minutes or less depending on terrain and travel characteristics, (b) homogeneity with respect to socioeconomic or demographic characteristics, (c) "limited interactions with contiguous areas," and (d) populations of at least 20,000 (Orlans et al. 2002). The features of adjoining areas are also important. Shortage areas should not be contiguous with another area that has adequate capacity to provide services to the area (Orlans et al. 2002).

Despite the obvious relevance of space in modeling geographical dental profession service levels, spatial factors have received little attention in the literature. The wider literature on health profession distribution seems also to have generally overlooked the importance of spatial variables and the need for spatial econometric modeling. It is not that researchers have ignored the spatial dimension altogether, but rather that they have rarely been formally introduced into models of health profession distribution. For example, Newhouse et al. (1982) examine the relationship between urban hierarchy and prevalence of physician specialists. Wade and House (2008) and Hong and Kindig (1992) recognize that travel and commuting patterns will affect the location of services but never formally test the relationship.

Regional scientists would argue that space cannot be ignored. Central Place Theory holds that there is a certain geographical structure to service markets and that as a place grows in size, the range of goods and services (including health care services) provided increases. Moreover, health care professions might be expected to cluster because of agglomerative forces such as shared customers or inputs. The demand and supply characteristics of one area can be expected to affect the demand and supply of nearby areas. A relatively high number of dentists in one region might induce lower levels in a nearby region because of "border crossing" while favorable consumer demand conditions in one region might similarly attract patients to adjacent regions.

4 Methodology and Empirical Model

We estimate the reduced-form model of dentist location/distribution suggested by equation (4) above. Similar reduced form models to estimate the influence of demand and supply factors on health care profession distribution have been motivated by slightly different analytical frameworks (Carpenter and Neun 1999; Beazoglou et al. 1992). Definitions and data sources are listed in **Table 1**. The geographical units of analysis are counties and county equivalents (e.g., independent cities in selected states, parishes in Louisiana) in the contiguous U.S. states which constituted 3,108 counties.

Three dependent variables are used. The first dependent variable, ***ACTIVE,*** includes all professionally active dentists. Professionally active dentists may work in private practice or public and non-profit sector and also include dental school faculty/staff as well as military dentists.[3] As such, it will include some dentists who are less sensitive in their locational choices to local market characteristics. Two additional dependent variables are used to explore location interdependencies among different categories of dentists. The second dependent variable, ***PRIVATE***, consists of private-practice dentists, hypothesized to be more responsive to geographical demand-supply characteristics. This variable is used to explore the sensitivity of the results to choice of dependent variable and whether public dentists displace private dentists. A third dependent variable,

[3] The ADA defines a professionally active dentist as dentists "whose primary and/or secondary occupation is private practice (full or part-time), dental school faculty/staff member, armed forces, other federal services, state or local government employee, hospital staff dentist, graduate student/intern/resident, and other health/dental organization staff member" (American Dental Association 2010b). Active private practitioners consist of any of the first category.

SPECIALIST, which consists of all dentist specialists (e.g., oral and maxillofacial surgery, periodontists, prosthodontists, endodontists, orthodontists) is used to examine the location characteristics of a sub-category of dentists likely to draw from a wider market region. One hypothesis is that specialists are more concentrated at higher levels within an urban hierarchy. A competing hypothesis is that specialists locate in the vicinity of areas with large numbers of generalists in order to benefit from greater access to patient referrals.

Consumer demand for dental services is represented by several variables. Similar to Beazoglou et al. (1992), we use per capita income to reflect the finding that demand for dental services increases with income. Data on the prevalence of dental insurance at a local level was unavailable. Therefore, a proxy variable, the percentage of the population with health insurance (***PINSURE***), was used instead. Individuals without health insurance are unlikely to have dental insurance. Moreover, individuals with health insurance probably have a greater likelihood of accessing both health and dental services. Several variables are used to reflect varied preferences for dental services and oral health status such as percentage of the population with a college degree (***PCOLL***), percentage of the population 65 years and older (***PSENIOR***) and percentage of the population that is minority (***PMIN***). Three variables reflect differential transportation costs of accessing dental services (***AREA***, ***HIGHWAY***, and ***NETCOM***). Higher transportation costs will reduce the quantity demanded of dental services. Transportation costs increase, holding all else constant, the larger the county land area. Moreover, counties with Interstate highways should have easier access to points within the county than those without. A commuting variable is included because individuals are more likely to utilize dental services where they work because of lower transportation costs to sites near work.

Several geographical variables are used to represent supply-related influences on dentist location. Consistent with Goetz and Debertin (1996) Olfert et al. (2012), we hypothesize that amenities are important. Two variables are used to represent amenities, one for natural amenities (***AMENITY***) and another for creative milieu (***CREATIVE***). Geographical clustering may occur for in health care services. Clustering may occur because of central place theory, the tendency of higher order services to be offered at more centralized locations. These services may also cluster because dental services can be produced at lower cost in certain areas because of localization and urbanization economies in the health care sector. Localization economies are represented by concentration of other health care professionals in the area, in this case physicians per capita (***PHYSICIAN***) are used. Urbanization economies are represented by distances to cities of various sizes (***CITY10***, ***CITY25***, ***CITY100***, ***CITY250***, ***CITY500***, and ***CITY1000***).

Table 1: Variable Definitions and Data Sources

Variable	Definition	Data Source
Dependent		
ACTIVE	Number of professionally active dentists per 100,000 residents	Health Resources and Services Administration, Area Resource File, 2009-2010 and National Cancer Institute, Surveillance Epidemiology and End Results (SEER)
PRIVATE	Number of private practice dentists	Health Resources and Services Administration, Area Resource File, 2009-2010 and SEER
SPECIALIST	Number of private practice specialist dentists	Health Resources and Services Administration, Area Resource File, 2009-2010 and SEER
Demand Factors		
INC	Per capita income (in thousands)	U.S. Census Bureau, American Community Survey, 2005-2009
PINSURE	Percentage of population under 65 years of age with health insurance	U.S. Census Bureau, Small Area Health Insurance Estimates (SAHIE), 2007
PCOLLEGE	Percentage of population with college education	U.S. Census Bureau, American Community Survey, 2005-2009
PMIN	Percentage of population that is non-white or hispanic	U.S. Census Bureau, American Community Survey, 2005-2009
PSENIOR	Percentage of population 65 years or older	U.S. Census Bureau, American Community Survey, 2005-2009
AREA	Land area in square miles	U.S. Census Bureau, County and City Data Book, 2007
HIGHWAY	Interstate highway mileage greater than zero	Bureau of Transportation Statistics, National Transportation Atlas Database, National Highway Planning Network, 2010

Table 1: Variable Definitions and Data Sources

Variable	Definition	Data Source
NETCOM	Net commuting (incommuters-outcommuters) as a percentage of population, 2000	U.S. Census Bureau, Census 2000, County-to-County Worker Flow Files
PHYSICIAN	Physicians per 100,000 residents (DO and MD), 2007	Health Resources and Services Administration, Area Resource File, 2009-2010
CITY10	Distance to a place of at least 10,000 residents in miles	U.S. Census Bureau data via MABLE/Geocorr2K[4]
CITY25	Distance to a place of at least 25,000 residents in miles	U.S. Census Bureau data via MABLE/Geocorr2K
CITY100	Distance to a place of at least 100,000 residents in miles	U.S. Census Bureau data via MABLE/Geocorr2K
CITY250	Distance to a place of at least 250,000 residents in miles	U.S. Census Bureau data via MABLE/Geocorr2K
CITY500	Distance to a place of at least 500,000 residents in miles	U.S. Census Bureau data via MABLE/Geocorr2K
CITY1000	Distance to a place of at least 1,000,000 residents in miles	U.S. Census Bureau data via MABLE/Geocorr2K
AMENITY	Natural amenities scale	U.S. Department of Agriculture, Economic Research Service, Natural Amenities Scale[5]
CREATIVE	Creative class share of employment, 2000	U.S. Department of Agriculture, Economic Research Service, Creative Class County Codes[6]
EDSPEND	State and local primary and secondary education spending per capita	U.S. Census Bureau, 2002 Census of Governments
PROPTAX	State and local property taxes per capita	U.S. Census Bureau, 2002 Census of Governments
SALESTAX	State and local sales tax per capita	U.S. Census Bureau, 2002 Census of Governments
INCTAX	State and local income taxes per capita	U.S. Census Bureau, 2002 Census of Governments

[4]Distance was measured from county population centroid to place county centroids using "as the crow flies" distance computed using the Great Circle Distance formula. Population centroids were computed on the basis of 2000 population and census boundaries using the MABLE/Geocorr2K: Geographic Correspondence Engine with Census 2000 Geography. http://mcdc2.missouri.edu/websas/geocorr2k.html,

[5]Accessed June 22, 2011. http://www.ers.usda.gov/Data/NaturalAmenities/

[6]Accessed June 22, 2011. http://www.ers.usda.gov/Data/CreativeClassCodes/

Variable	Definition	Data Source
Public Policy		
SCHOOL	Dental school located in county	American Dental Association (2010a)
STSCHOOL	Dental school located in state	American Dental Association (2010a)
DHPPI	Index of dental hygienist practice restrictions, 2001	Wing et al. (2005)
PMED	Percentage of children 1-18 years on Medicaid receiving dental services, 2009	Pew Center on the States (2011)
MEDFEES	Medicaid rates as a percentage of dentists' median retail fees, 2010	Pew Center on the States (2011)
Other		
PUBDEN	Public dentists per 100,000 residents, 2007	Health Resources and Services Administration, Area Resource File, 2009-2010
GENDEN	Generalist private practice dentists per 100,000 residents, 2007	Health Resources and Services Administration, Area Resource File, 2009-2010

Table 1: Variable Definitions and Data Sources

A group of variables are used to represent state policy choices that may affect either local consumer demand or dentist supply. Several states are studying the possibility of establishing dental schools to increase the statewide availability and reduce disparities in the regional distribution of dentists. ***SCHOOL***, a variable that measures the presence of an accredited dental school in the county, may increase the availability of dentists because of the presence of school clinics staffed by faculty, residents, and students who provide below market rate dental services. On the other hand, these dental services may displace ones offered by private-practice dentists. ***STSCHOOL*** is a dummy variable that indicates whether a dental school is located within the state affects entrance to the dental workforce. A state dental school could boost the workforce by selecting matriculants who place higher amenity values on locating within the state and are thereby willing to accept lower wages to work in a state practice. A regulatory variable, ***DHPPI***, is used to reflect the restrictiveness of state laws regarding dental hygienists, which could result in substitution of dentists to provide preventive care. The DHPPI (Dental Hygiene Professional Practice Index) is a 100 point scale measuring the legal and regulatory environment, dentist supervision requirements, range of tasks allowed for dental hygienists, and dental hygienist insurance reimbursement allowance, with higher values indicating a less restrictive regulatory environment for dental hygienists and greater likelihood that they would be used in place of dentists for preventive dental care. Two variables (***PMED*** and ***MEDFEES***) represent state policies that affect the likelihood of children enrolled in Medicaid and CHIP being able to access private dental services.

Analyses of private-practice and specialist dentist location rely on two additional variables. For the private practice dentist regressions, the number of dentists working outside of a private practice setting such as community health clinics, public health departments, military bases, education, and hospitals (***PUBDEN***) is used to gauge whether such dentists displace private dentists in local dental markets.[7] If these dentists serve patients who are otherwise unlikely to receive care, they may have little impact on private practice dentists. They may potentially even improve the balance sheets of private practice dentists if they free private dentists from providing below cost or charity care. Or, they could improve future private practice demand if tastes and preferences for oral health are altered or patients retain their teeth and as a result demand more maintenance care in the future than would otherwise have been the case. For the specialty dentist regression, a variable representing the number of general practitioners ***GENDEN*** is used to determine whether private practice specialists respond to the relative number of private practice general practitioners in their location choices.

Each dependent and independent variable was rescaled (or studentized) by subtracting its mean and dividing by its standard deviation. Doing so accomplishes two things. First, it reduced muticollinearity as measured by the condition index to a value below 10. Variance inflation factors were already less than 10 and were not affected by these variable transformations. Therefore, multicollinearity is not a problem. More importantly, rescaling was needed to facilitate the matrix inversions that the spatial regression techniques used. This technique was recommended by Bivand (2008) and LeSage and Pace (2009).

We start our analysis by running baseline Ordinary Least Squares regression. This formed the basis for conducting Lagrange Multiplier tests for the presence of spatial autocorrelation. Five tests were conducted: (a) the simple LM test for error dependence (LMerr), (b) the simple LM test for a missing spatially lagged dependent variable (LMlag), (c) the robust LM test for error dependence (RLMerr), (d) the robust LM test for spatially lagged dependent variable (RLMlag), and (e) a blended test for both lagged dependent variable and error dependence (SARMA). The former two are the Lagrange Multipliers incorporating the spatial dependence restrictions based on Anselin (1988). The middle two are LM tests that are robust with respect to misspecification based on the alternative form of spatial dependence based on Anselin et al. (1996). SARMA tests for a model involving both spatial errors and spatial lags. Two choices of weights matrix (W) were used for testing spatial autocorrelation and

[7] The exact practice settings adopted from the Area Resource File were state or local government, health organization, intern/resident, armed forces and other federal services, faculty, and other.

for estimating spatial econometric models. One was a contiguity-based spatial weight matrix that used the queen criterion (i.e., horizontal, vertical, and diagonal contiguity) to define neighbors. The other was a distance-based spatial weight matrix based on 10 nearest neighbors. The results were not sensitive to the choice between the two. Therefore, only the testing and estimation results for 10 nearest neighbors are reported in the next section.

In order to choose the most appropriate model, comparisons are made among Ordinary Least Squares (OLS) (equation 5) and three types of spatial regression models: the Spatial Autoregressive Model (SAR) (equation 6), the Spatial Error Model (SEM) (equation 7), and the Spatial Durbin Model (SDM) (equation 8).

$$y = X\beta + \epsilon \tag{5}$$

$$y = \rho W y + X\beta + \epsilon \tag{6}$$

$$y = X\beta + u \tag{7}$$

$$u = \rho W u + v$$

$$y = \rho W y + X\beta + \lambda W X + \epsilon \tag{8}$$

$$\epsilon \sim N(0, \sigma^2 I_n) \qquad u \sim N(0, \sigma^2 I_n)$$

Each of these spatial models has a slightly different motivation as explained in LeSage and Pace (2009). The SAR is motivated by a belief that the dependent variable is spatially autocorrelated. This situation would occur if dentist density was systematically associated with higher or lower dentist densities in nearby counties. The SEM model is motivated by the belief that that the error term is spatially autocorrelated. This situation would occur if the model omitted variables from the specification that were correlated over space. For example, there may be oral health status variables reflecting regional tastes and preferences that are not included in the model. The SDM model is motivated by the belief that omitted independent variables are correlated over space and also correlated with a model independent variable. For example, Appalachian region residents may exhibit similar tastes and preferences for oral health and Appalachian residency could be highly correlated with included independent variables such as natural landscape features (incorporated into the Amenity measure) or socioeconomic status variables. In addition to theoretical motivations, formal tests among the competing models can be conducted. LeSage and Pace (2009) show that OLS, SAR, and SEM are nested within SDM and that SDM will produce unbiased estimators. Log likelihoods can be used to choose among the competing models.

LeSage and Pace caution against comparing coefficient estimates from the SDM with OLS coefficient estimates. Individual elements of the β coefficient vector can be interpreted as the marginal effect of a unit change in the corresponding element of the design matrix X. In contrast, SDM coefficient estimates like other models incorporating a lagged dependent variable (e.g., SAR, Spatial Autocorrelation Model (SAC), Spatial Autoregressive Moving Average Model (SARMA)) require a different interpretation. For the SDM model, variation in dentists per capita is related to the concentration of dentists in nearby counties represented by the spatial lag term Wy in addition to the values of independent variables in nearby counties Wx. Therefore, we need to account for the fact that a change in the value of a independent variable for region i affects not only the concentration of dentists in region i y_i (the value of the β estimate from the SDM) but percolates through space to affect nearby neighbor dentist concentrations y_j which in turn feed back into dentist concentration in region i y_i. The summative effect of the two items is termed the "direct impact." Also, we need to account for the fact that a change in the value of an independent variable r for region i affects the concentration of dentists in region j y_j. This effect is termed the "indirect impact." The "total impact" is the sum of indirect and total impacts. Since these impacts vary by observation, LeSage and Pace compute average impacts which provides a summary picture of the impact of the marginal change in the independent variable. Statistical tests based on Bayesian Markov Chain Monte Carlo (MCMC) methods explained further in LeSage and Pace (2009) are used to test for impact statistical significance.

We conducted the tests and estimations using R statistical software. The OLS estimates were obtained using the `lm` (linear model) function from the base stats package. Spatial autocorrelation tests and spatial model estimations were conducted using functions from the spdep package (Bivand 2008;Bivand 2011) including the functions `lm.LMtests` (Lagrange Multiplier diagnostics for spatial dependence in linear models), `lagsarlm` (SAR and SDM model estimation), `errorsarlm` (SEM model estimation), `impacts` (calculation of direct, indirect, and total impacts for the SDM and statistical significance tests), and `predict.sarlm` (predictions).

5 Results

Table 2 shows the results for Lagrange Multiplier tests for spatial autocorrelation for the OLS model. Results indicate the presence of spatial correlation for the professionally active and private practice OLS regressions consistent with spatial effects in the error and lag terms. These results are also favorable for a SDM specification. However, results for dentist specialists suggest no spatial dependence. **Table 3** presents the results of log likelihood tests for each model. Results indicate that SAR and SEM provide negligible model fit improvement while SDM represents a marked improvement. In each instance, Log Likelihood Ratio tests indicate statistical significance with p values substantially less than .001. Based on this criterion alone,the SDM would be selected.

Table 2: LaGrange Multiplier Test Results (p values)

Statistic	Active	Private	Specialist
LMerr	0.0000	0.0000	0.5710
LMlag	0.0000	0.0000	0.4730
RLMerr	0.0032	0.0253	0.9601
RLMlag	0.0981	0.0162	0.6576
SARMA	0.0000	0.0000	0.7720

Table 3: Log Likelihood Results

Statistic	Active	Private	Specialist
OLS	-3016.439	-3236.432	-3256.815
SAR	-3003.206	-3223.523	-3256.80
SEM	-3003.478	-3221.161	-3256.786
SDM	-2955.626	-3180.905	-3226.335

The results of an OLS regression for all professionally active dentists are presented in **Table 4**. Coefficient estimates that are statistically significant at the p=.05 level are highlighted in bold. These results show that consumer demand characteristics are important. Higher insurance coverage (***PINSURE***) and college attainment (***PCOLLEGE***) are associated with higher dentist density. Higher percentages of senior citizens (***PSENIOR***) are associated with higher dentist prevalence, a result consistent with the evidence that seniors spend more per capita on dental care than other age groups. More net in-commuting also boosts the relative number of dentists. Many working-age individuals can be expected to often choose providers close to their workplace rather than their residence (Hong and Kindig 1992). Some consumer demand variables were statistically insignificant or had unexpected signs. The percentage of population minority and per capita income were insignificant at the .05 level but had the expected signs. Variables reflecting costs of travel such as the presence of an interstate (***HIGHWAY***) and county land area (***AREA***) were statistically insignificant. Beazoglou et al. (1992) also found land area to be statistically insignificant.

Supply factors are also important. Both natural amenity (***AMENITY***) and creative (***CREATIVE***) class variables are statistically significant with the expected signs, suggesting that amenities attract more dentists. Coefficients for ***CITY250*** and ***CITY1000*** suggest attraction to the largest cities but repulsion from intermediate sized cities. The positive coefficient for ***PHYSICIAN*** indicates that dentists tend to cluster around other health professionals such as physicians. This result suggests the existence of some localization economies in the health care sector. Indeed, medical and dental practitioners often colocate in professional buildings. Both dental school variables (***SCHOOL***) and

(***STSCHOOL***) are statistically significant. The former finding is expected since dental school faculty and dental residents will be reflected in the dentist figures. Even if some local private-practice dentists were displaced, this coefficient would still be positive if school affiliated dentists more than offset the loss. The coefficient on ***STSCHOOL*** suggests that state dental schools may boost state dentist numbers, perhaps by being more likely to select students who place a high amenity value on staying in place. City distance variables show varied effects, but as will be shown below, the results disappear when spatial dependency is introduced. The single regulatory variable, ***DHPPI***, is statistically significant with the expected negative sign, meaning that less restrictive state laws against dental hygienists (i.e., higher DHPPI values) reduce the relative quantity of dentists. The two taxation variables have unexpected positive signs (***SALESTAX***, ***INCTAX***).

Table 4: Professionally Active Dentist OLS

	Estimate	Std.Error	t value	Pr(>|t|)
(Intercept)	-0.0001	0.0115	-0.01	0.9912
INC	0.0415	0.0234	1.78	0.0758
PINSURE	**0.1115**	**0.0161**	**6.93**	**0.0000**
PCOLLEGE	**0.1704**	**0.0311**	**5.49**	**0.0000**
PMIN	-0.0294	0.0156	-1.88	0.0599
PSENIOR	**0.0471**	**0.0151**	**3.12**	**0.0018**
AREA	0.0095	0.0142	0.67	0.5059
HIGHWAY	0.0134	0.0131	1.03	0.3051
NETCOM	**0.1275**	**0.0142**	**8.98**	**0.0000**
PHYSICIAN	**0.2477**	**0.0164**	**15.11**	**0.0000**
CITY10	-0.0167	0.0188	-0.89	0.3729
CITY25	0.0011	0.0192	0.06	0.9547
CITY100	0.0201	0.0222	0.90	0.3659
CITY250	**0.0640**	**0.0236**	**2.71**	**0.0067**
CITY500	0.0217	0.0191	1.14	0.2562
CITY1000	**-0.0340**	**0.0154**	**-2.20**	**0.0279**
AMENITY	**0.0378**	**0.0169**	**2.24**	**0.0250**
CREATIVE	**0.2228**	**0.0319**	**6.98**	**0.0000**
EDSPEND	-0.0255	0.0149	-1.71	0.0877
PROPTAX	-0.0318	0.0164	-1.94	0.0527
SALESTAX	**0.0404**	**0.0139**	**2.91**	**0.0036**
INCTAX	**0.0348**	**0.0156**	**2.24**	**0.0255**
SCHOOL	**0.2230**	**0.0125**	**17.87**	**0.0000**
STSCHOOL	**0.0379**	**0.0146**	**2.60**	**0.0093**
DHPPI	**-0.0349**	**0.0147**	**-2.38**	**0.0173**
PMED	-0.0077	0.0131	-0.59	0.5563
MEDFEES	-0.0059	0.0139	-0.43	0.6677

R2=.5918

The SDM model has an estimated spatial autocorrelation coefficient, ρ, with a value of 0.1316 that is highly significant (p=0.0006). This indicates that higher nearby county concentrations of dentists have a small but statistically significant positive effect on dentists per capita. **Table 5** provides estimated direct, indirect, and total impacts and z-test statistics for the professionally active dentist SDM. The results are largely consistent with previous results. However, some explanatory factors are enhanced and others diminished. For instance, the relative minority population (***PMIN***) and property taxes per capita (***PROPTAX***) variables now have expected negative direct impact on dentists. ***CITY250***, ***CITY1000***, ***SALESTAX*** and ***INCTAX*** are no longer statistically significant but ***EDSPEND*** has an unexpected negative direct impact.

Some spillover effects are revealed. For example, a dental school in one county may increase dentists available in neighboring counties as well as the county where it is located. Higher per capita income, more net incommuting and greater education spending in one county may boost the availability of dentists in adjacent counties. An interstate highway in one county may decrease the availability of dentists in a nearby county. This result is consistent with the expectation that interstate highways alter service market boundaries to the detriment of adjacent unserved counties (Rephann and Isserman 1994).

Table 6 shows OLS regression results for dentists working in private practices. The model should have greater relevancy to explaining private practice location than the professionally active dentist location since consumer market factors should be more important. This does appear to be the case. Two measures of local consumer demand (***INC*** and ***PMIN***) are statistically significant in this regression whereas they were not for the OLS regression of professionally all active dentists. In most instances, the coefficients for private practice dentists have the same sign and statistical significance as the earlier model. One exception is the city distance variable (***CITY10***). Results indicate that increasing distance from a city of at least 10,000 residents is a barrier to dentist location. Dentists are more likely to be present in counties in close proximity to areas having this small level of urbanization. Like the previous OLS regression, the Medicaid access variables for children (***PMED*** and ***MEDFEES***) are statistically insignificant. These results may reflect the fact that other barriers exist to private practitioners accepting Medicaid patients than enrollment and compensation features of state programs, such as added administrative burdens and higher rates of missed appointments. Public dentists (***PUBDEN***) per capita is positively associated with private dentists, which contradicts the claim that dentists outside of private practice displace private practitioners, at least at the relatively low levels found in the data.

The SDM model has an estimated spatial autocorrelation coefficient, ρ, with a value of 0.1316 that is highly significant (p=0.0006). Once again, higher prevalence of private practice dentists in nearby counties has a small but statistically significant positive effect. **Table 7** provides estimated impacts. Several

Table 5: Professionally Active Dentist SDM

	Direct	Pr(>|z|)	Indirect	Pr(>|z|)	Total	Pr(>|z|)
INC	-0.0162	0.5456	**0.2226**	**0.0001**	**0.0206**	**0.0001**
PINSURE	**0.1303**	**0.0000**	-0.0440	0.1462	**0.0863**	**0.0029**
PCOLLEGE	**0.1835**	**0.0000**	-0.0730	0.3665	0.1105	0.1743
PMIN	**-0.0624**	**0.0125**	0.0026	0.8976	**-0.0598**	**0.0223**
PSENIOR	**0.0592**	**0.0004**	**-0.0912**	**0.0122**	-0.0320	0.3466
AREA	-0.0096	0.6599	-0.0334	0.3256	-0.0430	0.1623
HIGHWAY	0.0261	0.0520	**-0.0734**	**0.0496**	-0.0474	0.2221
NETCOM	**0.1335**	**0.0000**	**0.1304**	**0.0163**	**0.2639**	**0.0000**
PHYSICIAN	**0.2475**	**0.0000**	0.0058	0.9035	**0.2533**	**0.0000**
CITY10	-0.0399	0.0613	0.1016	0.0512	0.0617	0.1503
CITY25	-0.0179	0.5660	0.0020	0.9919	-0.0159	0.6324
CITY100	0.1142	0.0873	-0.1566	0.0505	-0.0424	0.1885
CITY250	0.1428	0.1867	-0.0814	0.5242	**0.0614**	**0.0330**
CITY500	-0.0532	0.6949	0.0819	0.5918	0.0287	0.3564
CITY1000	0.1352	0.4955	-0.1704	0.3945	-0.0353	0.0661
AMENITY	-0.0108	0.7530	0.0729	0.0988	**0.0620**	**0.0404**
CREATIVE	**0.2263**	**0.0000**	-0.1381	0.1209	0.0882	0.2288
EDSPEND	**-0.0472**	**0.0045**	**0.1029**	**0.0019**	0.0557	0.0790
PROPTAX	**-0.0349**	**0.0370**	**-0.0853**	**0.0286**	**-0.1201**	**0.0017**
SALESTAX	0.0307	0.2394	-0.0051	0.9585	0.0256	0.1884
INCTAX	0.0144	0.7156	-0.0044	0.9838	0.0101	0.6545
SCHOOL	**0.2393**	**0.0000**	**0.2544**	**0.0000**	**0.4937**	**0.0000**
STSCHOOL	**0.0963**	**0.0011**	**-0.0907**	**0.0212**	0.0056	0.7955
DHPPI	**-0.1705**	**0.0000**	**0.1383**	**0.0054**	-0.0322	0.1150
PMED	0.0265	0.5045	-0.0425	0.3230	-0.0160	0.3367
MEDFEES	0.0149	0.7383	-0.0475	0.3016	-0.0326	0.0975

statistically significant OLS results dissipate when comparing SDM direct impact results to the OLS regression coefficients. ***INC***, ***PMIN***, ***CITY250***, ***CITY1000***, ***AMENITY***, and ***INCTAX*** direct impacts are not statistically significant. On the other hand, the highway and dental school variables become positive and statistically significant. Therefore, a dental school in the county does not appear to displace private practice dentists in the area but may even enhance the supply, perhaps through mechanisms identified by Isabel and Paula (2010). The state school direct impact is also statistically significant in contrast to the findings of Bailit and Beazoglou (2003). This result suggests a possible role for state dental education in improving the state supply and distribution of private practice dentists.

Indirect impact results point to the possibility of demand and supply spatial spillovers to neighboring counties. Once again, a dental school in one county may increase the relative number of private practice dentists available in proximate counties. Higher per capita income, greater education spending, more natural

Table 6: Private Practice Dentist OLS

	Estimate	Std.Error	t value	Pr(>|t|)
(Intercept)	-0.0002	0.0124	-0.02	0.9861
PUBDEN	**0.0340**	**0.0146**	**2.33**	**0.0197**
INC	**0.0597**	**0.0251**	**2.38**	**0.0176**
PINSURE	**0.1468**	**0.0173**	**8.49**	**0.0000**
PCOLLEGE	**0.1289**	**0.0334**	**3.85**	**0.0001**
PMIN	**-0.0461**	**0.0168**	**-2.74**	**0.0062**
PSENIOR	**0.0831**	**0.0162**	**5.12**	**0.0000**
AREA	0.0223	0.0153	1.46	0.1457
HIGHWAY	0.0188	0.0141	1.34	0.1800
NETCOM	**0.1981**	**0.0153**	**12.96**	**0.0000**
PHYSICIAN	**0.1440**	**0.0181**	**7.96**	**0.0000**
CITY10	**-0.0530**	**0.0201**	**-2.63**	**0.0086**
CITY25	-0.0002	0.0206	-0.01	0.9924
CITY100	0.0295	0.0239	1.23	0.2170
CITY250	**0.0800**	**0.0253**	**3.16**	**0.0016**
CITY500	0.0022	0.0205	0.11	0.9153
CITY1000	**-0.0427**	**0.0166**	**-2.58**	**0.0101**
AMENITY	**0.0486**	**0.0181**	**2.69**	**0.0072**
CREATIVE	**0.3038**	**0.0343**	**8.86**	**0.0000**
EDSPEND	**-0.0361**	**0.0160**	**-2.25**	**0.0244**
PROPTAX	-0.0128	0.0177	-0.72	0.4689
SALESTAX	**0.0666**	**0.0149**	**4.47**	**0.0000**
INCTAX	**0.0446**	**0.0167**	**2.67**	**0.0076**
SCHOOL	0.0193	0.0139	1.39	0.1642
STSCHOOL	0.0180	0.0157	1.15	0.2504
DHPPI	**-0.0330**	**0.0157**	**-2.10**	**0.0360**
PMED	-0.0100	0.0141	-0.71	0.4791
MEDFEES	0.0039	0.0149	0.26	0.7931
R2=.5296				

amenities, and net in-commuting are positively associated with increased dentist service levels nearby while percentage of seniors and percentage of the labor force in the creative class have a depressing effect.

Table 8 presents the results of OLS regression for the number of private-practice specialists per 100,000 population. Results are similar to those for all private practice dentists in many instances. Exceptions are relative minority population and educational spending per capita, which are positively associated with specialists, relative senior population which is statistically insignificant, and percentage of children on Medicaid receiving dental services which has an unexpected negative coefficient. The presence of a dental school within the state is associated with a greater number of specialists as it was for other dentist

Table 7: Private Practice Dentist SDM

	Direct	Pr(>|z|)	Indirect	Pr(>|z|)	Total	Pr(>|z|)
PUBDEN	**0.0304**	**0.0355**	-0.0272	0.5443	0.0031	0.9428
INC	0.0008	0.9573	**0.2611**	**0.0000**	**0.2618**	**0.0000**
PINSURE	**0.1615**	**0.0000**	-0.0321	0.4237	**0.1294**	**0.0001**
PCOLLEGE	**0.1392**	**0.0000**	-0.0650	0.5205	0.0741	0.3252
PMIN	-0.0500	0.0749	-0.0334	0.4225	**-0.0834**	**0.0035**
PSENIOR	**0.1078**	**0.0000**	**-0.1106**	**0.0031**	-0.0028	0.9283
AREA	0.0038	0.8453	-0.0339	0.3568	-0.0301	0.3232
HIGHWAY	**0.0273**	**0.0430**	-0.0574	0.1968	-0.0301	0.5282
NETCOM	**0.1999**	**0.0000**	**0.1342**	**0.0103**	**0.3341**	**0.0000**
PHYSICIAN	**0.1415**	**0.0000**	0.0305	0.7324	**0.1720**	**0.0150**
CITY10	**-0.0835**	**0.0001**	**0.1208**	**0.0460**	0.0373	0.5416
CITY25	-0.0101	0.7092	-0.0124	0.9209	-0.0225	0.6715
CITY100	0.0822	0.2613	-0.1106	0.2051	-0.0284	0.4524
CITY250	-0.0026	0.9898	0.0848	0.5005	**0.0823**	**0.0142**
CITY500	-0.1204	0.3560	0.1392	0.3153	0.0189	0.5601
CITY1000	0.3811	0.1237	-0.4368	0.0825	**-0.0557**	**0.0093**
AMENITY	-0.0263	0.3183	**0.1293**	**0.0014**	**0.1030**	**0.0009**
CREATIVE	**0.3164**	**0.0000**	**-0.1935**	**0.0128**	0.1228	0.1369
EDSPEND	**-0.0590**	**0.0008**	**0.0867**	**0.0350**	0.0277	0.5147
PROPTAX	-0.0163	0.4000	-0.0733	0.0944	**-0.0896**	**0.0422**
SALESTAX	**0.0696**	**0.0028**	-0.0194	0.7191	**0.0502**	**0.0202**
INCTAX	0.0263	0.4466	-0.0024	0.9948	0.0239	0.3580
SCHOOL	**0.0289**	**0.0184**	**0.2021**	**0.0008**	**0.2311**	**0.0003**
STSCHOOL	**0.0784**	**0.0451**	0.2021	0.1303	-0.0009	0.8768
DHPPI	**-0.1641**	**0.0002**	**0.1246**	**0.0119**	-0.0395	0.0774
PMED	0.0171	0.6257	-0.0325	0.4912	-0.0155	0.5033
MEDFEES	0.0276	0.3722	-0.0519	0.1867	-0.0244	0.2256

categories. But, having a local dental school decreases the number of specialists in contrast to the boost provided in all private practitioners. Approximately 60 percent of dental faculty are specialty dentists and their intramural or extramural services could displace those offered by private practice specialists.

Specialists are more common in counties with a relatively high number of general practitioners (***GENDEN***), supporting the hypothesis that patient referrals are an important component of the location decision. But, place hierarchy may still play a residual role. The negative and statistically significant coefficients on ***CITY10*** and ***CITY25*** suggest that specialists are attracted to places further up the urban hierarchy. Increasing distance from a city of at least 10,000 residents decreases the relative number of general practitioners. For specialists, increasing distance from a city of at least 25,000 people also decreases the relative number of specialists.

Table 8: Specialty Practice Dentist OLS

	Estimate	Std.Error	t value	Pr(>|t|)
(Intercept)	-0.0000	0.0124	-0.00	0.9996
GENDEN	**0.1653**	**0.0166**	**9.93**	**0.0000**
INC	**0.0632**	**0.0253**	**2.50**	**0.0124**
PINSURE	**0.0375**	**0.0176**	**2.13**	**0.0332**
PCOLLEGE	**0.1469**	**0.0336**	**4.37**	**0.0000**
PMIN	**0.0362**	**0.0169**	**2.14**	**0.0324**
PSENIOR	0.0291	0.0164	1.78	0.0757
AREA	0.0230	0.0154	1.50	0.1345
HIGHWAY	0.0254	0.0141	1.80	0.0727
NETCOM	**0.1031**	**0.0157**	**6.58**	**0.0000**
PHYSICIAN	**0.1732**	**0.0178**	**9.71**	**0.0000**
CITY10	**-0.1288**	**0.0203**	**-6.35**	**0.0000**
CITY25	**-0.0515**	**0.0207**	**-2.49**	**0.0129**
CITY100	0.0185	0.0240	0.77	0.4421
CITY250	**0.0748**	**0.0255**	**2.93**	**0.0034**
CITY500	**-0.0726**	**0.0206**	**-3.52**	**0.0004**
CITY1000	0.0124	0.0167	0.74	0.4564
AMENITY	0.0248	0.0182	1.36	0.1734
CREATIVE	**0.1856**	**0.0348**	**5.33**	**0.0000**
EDSPEND	**0.0362**	**0.0162**	**2.24**	**0.0252**
PROPTAX	-0.0217	0.0178	-1.22	0.2227
SALESTAX	0.0259	0.0150	1.72	0.0851
INCTAX	-0.0014	0.0168	-0.08	0.9331
SCHOOL	**-0.0268**	**0.0135**	**-1.98**	**0.0473**
STSCHOOL	**0.0389**	**0.0157**	**2.47**	**0.0134**
DHPPI	**-0.0565**	**0.0158**	**-3.56**	**0.0004**
PMED	**-0.0301**	**0.0142**	**-2.13**	**0.0334**
MEDFEES	-0.0029	0.0150	-0.19	0.8477
R2=.5236				

The SDM model has an estimated spatial autocorrelation coefficient, ρ, with a value of -0.042299 that is not statistically significant (p=0.3101). Full impact results are provided in **Table 9**. They show that only five indirect impacts are statistically significant in contrast to seven for all professionally active dentists and eight for private practice dentists. These results may reflect that the fact that included independent variables such as relative number of generalist dentists and city distance variables already adequately capture many of the spatial contextual factors important for specialists.

The SDM model does produce pronounced differences in estimation results compared to the OLS regression. Focusing on direct impacts, ***GENDEN***, ***INC***, ***PCOLLEGE***, ***PMIN***, ***NETCOM***, ***PHYSICIAN***, ***CITY10***, ***CITY25***, ***CREATIVE***, and ***SCHOOL*** have the same signs and are statistically significant. Seven variables (***PINSURE***, ***CITY250***, ***CITY500***, ***EDSPEND***, ***STSCHOOL***, ***DHPPI***, and ***PMED***) switch from being statistically significant to statistically insignificant while four variables (***AREA***, ***PSENIOR***, ***HIGHWAY***, and ***CITY1000***) become statistically significant. The coefficient signs on ***AREA*** are contrary to expectations that county land area size increases the costs of accessing dental while the coefficient results on ***CITY1000*** suggests diseconomies for specialist services with closer proximity to the largest category of cities. One indirect impact has a ready explanation. The indirect impact for ***GENDEN*** is consistent with expectations that a greater number of general practitioners should boost the number of specialist providers in neighboring counties by providing referrals to specialists that draw from larger catchment areas in the region.

Table 9: Specialty Practice Dentist SDM

	Direct	Pr(>|z|)	Indirect	Pr(>|z|)	Total	Pr(>|z|)
GENDEN	**0.1607**	**0.0000**	***0.0876***	***0.0359***	**0.2483**	**0.0000**
INC	**0.0784**	**0.0079**	0.0204	0.7244	**0.0988**	**0.0470**
PINSURE	0.0089	0.6637	0.0604	0.1332	**0.0693**	**0.0115**
PCOLLEGE	**0.1505**	**0.0001**	-0.1200	0.1248	0.0305	0.6535
PMIN	**0.0779**	**0.0109**	-0.0488	0.2364	0.0292	0.1618
PSENIOR	**0.0494**	**0.0137**	-0.0640	0.0598	-0.0146	0.5754
AREA	**0.0594**	**0.0065**	**-0.0972**	**0.0069**	-0.0379	0.1879
HIGHWAY	**0.0307**	**0.0486**	-0.0316	0.3309	-0.0009	0.9355
NETCOM	**0.1056**	**0.0000**	-0.0626	0.1595	0.0429	0.4662
PHYSICIAN	**0.1608**	**0.0000**	0.0674	0.1566	**0.2282**	**0.0000**
CITY10	**-0.1218**	**0.0000**	-0.0258	0.6806	**-0.1476**	**0.0005**
CITY25	**-0.1417**	**0.0000**	**0.1727**	**0.0009**	0.0310	0.3898
CITY100	0.0161	0.8175	-0.0064	0.9074	0.0097	0.7976
CITY250	0.1638	0.1698	-0.1241	0.3397	0.0397	0.1428
CITY500	-0.1743	0.2429	0.1343	0.3843	-0.0400	0.1001
CITY1000	**0.5613**	**0.0090**	**-0.5670**	**0.0105**	-0.0057	0.7994
AMENITY	-0.0340	0.2689	**0.1438**	**0.0006**	**0.1098**	**0.0003**
CREATIVE	**0.1814**	**0.0000**	0.0107	0.9407	**0.1921**	**0.0096**
EDSPEND	0.0299	0.0888	0.0314	0.3386	**0.0613**	**0.0488**
PROPTAX	-0.0251	0.1778	0.0251	0.5629	0.0001	0.9232
SALESTAX	0.0106	0.6766	0.0119	0.6824	0.0226	0.2273
INCTAX	-0.0061	0.8636	-0.0146	0.7454	-0.0208	0.3736
SCHOOL	**-0.0293**	**0.0363**	-0.0299	0.4144	-0.0592	0.1850
STSCHOOL	0.0706	0.0587	-0.0571	0.1749	0.0135	0.4746
DHPPI	-0.0221	0.6974	-0.0572	0.1657	**-0.0793**	**0.0000**
PMED	0.0443	0.2495	-0.0823	0.0557	**-0.0380**	**0.0274**
MEDFEES	-0.0265	0.5985	0.0265	0.6271	0.0000	0.9521

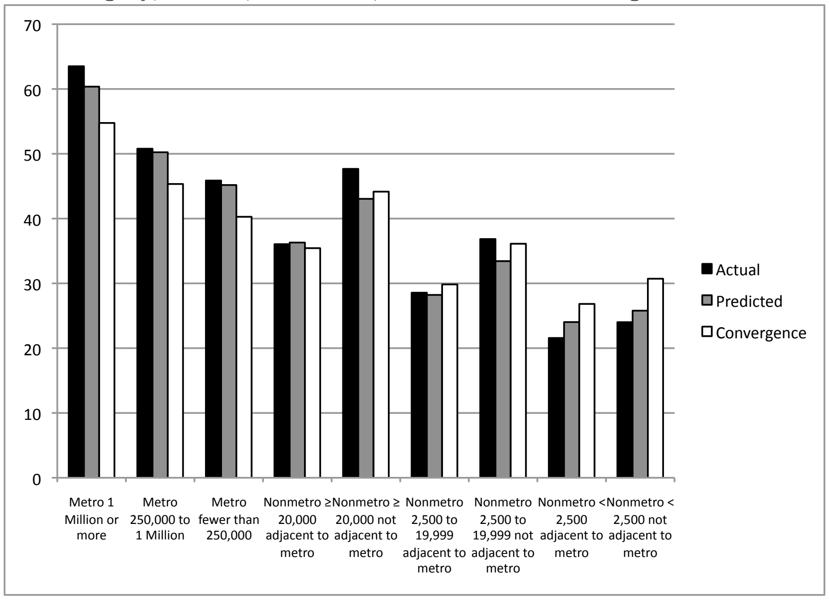
While these regression results confirm that county and spatial characteristics can explain a large portion of dentist disparities, not all of them are amenable to direct policy intervention. For example, it is impossible for a county to change its level or proximity to urbanization or alter its endowment of natural amenities, even though they play a role in dentist location choices. Although some variables might be amenable to policy intervention such as interstate highway construction or the establishment of new dental schools, such choices will be constrained by financial resources and other concerns (e.g., environment, over-saturation of dentist markets). Increasing the burden of dental hygienist regulation has the potential to boost the relative quantity of dentists but it would be undesirable from a consumer and public health vantage point. Results suggest, however, it may be possible to alter some aspects of regional demand through economic development policy and public health initiatives.

In order to investigate this issue further, we conduct a policy simulation where education achievement, income levels, and insurance coverage for nonmetropolitan areas are raised to values found in the average metropolitan county with one million population or more. That is to say, ***PCOLLEGE*** was changed to 26.2 percent, ***INC*** to $27,922, and ***PINSURE*** to 84.0 percent from lower average values. **Figure 6** shows the number of private practice dentists per 100,000 population by rural-urban continuum category along with the values predicted by the SDM regression. The third bar in the graph shows the predicted values based on the demand convergence criteria. The effect of this boost in county demand is to raise the relative number of predicted dentists by between 2 percent for nonmetropolitan counties with 20,000 or more urban population that are not adjacent to metropolitan areas and up to 21 percent for nonmetropolitan counties with less than 2,500 urban population not adjacent to metropolitan areas. This increase in demand also depresses somewhat dentist concentration in metropolitan areas by between 11 percent (metropolitan areas with fewer than 250,000 residents) to 9 percent (metropolitan areas with 1 million or more residents) because of spatial dependence. Even with this demand convergence, significant gaps remain.

6 Summary and Conclusion

This paper examines the distribution of dentists among U.S. counties along the rural-urban continuum. Retention of the dentist workforce is both a public health and economic development issue for rural communities. Dentist workforce availability has implications for oral health access, which in turn, can have an impact on the quality of life, health, and productivity of local residents. In addition, dentists form part of the non-tradable services sector and its erosion may affect the vitality of rural economies. Unfortunately, data indicate that nonmetropolitan counties have significantly lower levels of dentists per 100,000 residents than metropolitan areas and face the prospect of future erosion in the dentist workforce because of an aging workforce and greater difficulty attracting younger dentists who favor more urbanized practice locations.

Figure 6: Private Practice Dentists per 100,000 Residents by Rural-Urban Continuum Category, Actual, Predicted, and Demand Convergence



The paper develops a model of dentist location based on an economic framework with particular attention paid to spatial economic factors. Empirical results indicate that varied demand and supply factors can affect county dentist availability. Demand factors such as income, health insurance, and educational levels play an important part in dentist disparities. Moreover, supply policies such as the placement of dental schools and public dentistry may also play a role in rectifying imbalances. Increasing regulatory barriers to dental auxiliaries too can boost the number of dentists but doing so would be ill advised from a consumer and public health vantage point. No consistent evidence was found that fiscal and tax characteristics form a barrier to the attraction of dentists. Key determinants of dentist location such as urban configuration, presence of physician clusters, commuting patterns, and natural amenity levels are probably beyond the scope of direct policy remediation.

Evidence is presented to support several hypotheses regarding dentist location. Not surprisingly, specialist dentists are more likely to be found near counties with small cities (25,000 population or greater) while generalists are attracted to places with a lower population threshold (10,000). Moreover, they are more likely to locate in areas with a larger numbers of referring general practitioners. No evidence is found that dentists working outside of private practice displace private practitioners. Instead, more private practice dentists are found in areas with a greater relative number of public/non-profit dentists. Therefore, concern that publicly subsidized dental clinics near current levels might jeopardize a delicate market equilibrium and result in fewer private practitioners, as is sometimes heard, is not supported.

This work suggests several additional avenues for exploration. First, as previous researchers have noted (Mistretta 2007), interdependent dental and health care profession markets may cause endogeneity problems that require instrumental variable estimation. In particular, specialist and generalist dentists, public and private dentists, and dentists and physicians may affect one another's location decisions. Second, the role of dental auxiliaries and other dental practice inputs (e.g., capital, technology) in meeting demand for dental services was not explored. Third, the results here must be interpreted with the usual caution accorded results based on aggregate geographical data because of the possibility of ecological fallacy. Micro-level data on dentists could be used to make more valid inferences of locational behavior. Lastly, it would be useful to see if the findings here are generalizable to other health professions.

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